REPORT

OF THE

FORTY-EIGHTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

DUBLIN IN AUGUST 1878.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1879.

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ERRATA IN THE PRESENT VOLUME.

P. 304, line 25 :—*for* M_8 (at 155 + 47) *read* M_8 (at 160 + 49). [And in the Note on p. 103, Vol. for 1872 of these Reports, *for* R. A. 160°, N. Decl. 51° *read* R. A. 150°, N. Decl. 61°; and *for* R. A. 155°, N. Decl. 47° *read* R. A. 160°, N. Decl. 49° (the real places in Greg's and Heis' lists of 1864 and 1867, of their radiant-points M_8.)]

P. 304, line 38 :—*for* over the town of Beckingham, near Market Harborough *read* over a point between Buckingham and Market Harborough.

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Page 75 (Sections), line 3 *et seq.*,

for	88	*read*	88
	27		27
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OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be

published after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis*.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than 100 copies remain*, at one third of the Publication Price. Application to be made at the Office of the Association, 22 Albemarle Street, London, W.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons.—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.

1. The President for the time being of any Scientific Society publishing Transactions or, in his absence, a delegate representing him. *Claims under this Rule to be sent to the Assistant Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

*Organizing Sectional Committees.**

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

* Passed by the General Committee, Edinburgh, 1871.

From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,* and of preparing Reports thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first meeting.

An Organizing Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to settle the terms of their Report, after which their functions as an Organizing Committee shall cease.

Constitution of the Sectional Committees.†

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day, in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday, Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the Committee of the Section, and entered on the minutes accordingly.
3. Papers which have been reported on unfavourably by the Organizing Committees shall not be brought before the Sectional Committees.‡

* *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organizing Committees for the several Sections *before the beginning of the Meeting.* It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each Author should prepare an Abstract of his Memoir, of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before........................., addressed thus—"General Secretaries, British Association, 22 Albemarle Street, London, W. For Section ......" If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note.

† Passed by the General Committee, Edinburgh, 1871.

‡ These rules were adopted by the General Committee, Plymouth, 1877.

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Transactions. He will next proceed to read the Report of the Organizing Committee.* The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xix), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and one of them appointed to act as Secretary, for insuring attention to business.*

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

* This and the following sentence were added by the General Committee, 1871.

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

Notices regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made must (previously to the next Meeting of the Association) forward to the General Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one Meeting of the Association expire *a week before* the opening of the ensuing Meeting: nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, Professor A. W. Williamson, University College, London, W.C., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken, and the reading of communications, in the order previously made public, commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1.—To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.

2.—To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Assistant Secretary.

3.—Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed, during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London. LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Ackland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.

The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L. F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal. IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich. Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society. BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society. HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge. William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford. CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide. The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.

RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT. ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The Rev. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S. Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hinds, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.

JOSEPH DALTON HOOKER, M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndsean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de M. Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S. L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
DR W. B. CARPENTER, LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Earl of Chichester, Lord-Lieutenant of the County of Sussex The Duke of Norfolk The Right Hon. the Duke of Richmond, K.G., P.C., D.C.L. The Right Hon. the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S. Sir John Hawkshaw, F.R.S., F.G.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. Rev. Dr. Henry. Dr. Andrews, F.R.S. Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S. L. & E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Sir William Thomson, M.A., LL.D., D.C.L., F.R.S. L. & E. Professor Allen Thomson, M.D., LL.D., F.R.S. L. & E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S. L. & E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., F.R.S. L. & E., F.L.S., M.R.I.A. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. The Master Cutler Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., F.R.S., F.G.S. J. F. Moss, Esq.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries

MATHEMATICAL AND PHYSICAL SCIENCES.

COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.

Date and Place	Presidents	Secretaries
1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.

SECTION A.—MATHEMATICS AND PHYSICS.

Date and Place	Presidents	Secretaries
1835. Dublin......	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S., &c.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S. F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter......	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S.	Prof. W. K. Clifford, Prof. Forbes, J. W.L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol......	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J.W.L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford......	John Dalton, D.C.L., F.R S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

Date and Place	Presidents	Secretaries
1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.

Date and Place	Presidents	Secretaries
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E., F.C.S.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol......	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S., F.C.S. ...	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S., F.C.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Captain H. M. Denham, R.N.
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhope.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton	Leonard Horner, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Robert A. Austen, Dr. J. H. Norten, Prof. Oldham.—*Geography*, Dr. C. T. Beke.

Date and Place	Presidents	Secretaries
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh*	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool ..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL. D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. D. C. L. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, J. McKenny Hughes, L. C. Miall.

* At a meeting of the General Committee held in 1850, it was resolved "That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the 'Geographical and Ethnological Section,'" for Presidents and Secretaries of which see page xxxix.

Date and Place	Presidents	Secretaries
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull. M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol......	Dr. Thomas Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S............	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge*	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham.....................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman...	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D.......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. xxxviii.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.

* At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. xxxviii.

Date and Place	Presidents	Secretaries
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.........	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.*

1866. Nottingham	Prof. Huxley, LL.D., F.R.S. —*Physiological Dep.*, Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.*, Alf. R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter......	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.

* At a meeting of the General Committee in 1865, it was resolved:—"That the title of Section D be changed to Biology;" and "That for the word 'Subsection,' in the rules for conducting the business of the Sections, the word 'Department' be substituted.

Date and Place	Presidents	Secretaries
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres. R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, M.D., F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, M.D., F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.R.G.S., F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, M.A., F.R.S.—*Dep. of Anat. and Physiol*, Dr. J. G. McKendrick, F.R.S.E.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, LL.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister, M.D.—*Dep. of Anthropol.*, Francis Galton, M.A., F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E. (UNTIL 1847.)—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard......................	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.
1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844 York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.

Date and Place	Presidents	Secretaries

SECTION E.—PHYSIOLOGY.

1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford* ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	C. E. Paget, M.D...............	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath........	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birminghm.†	Prof. Acland, M.D, LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xxxiv.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard.....................	Dr. King.
1847. Oxford......	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull........	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.

* By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of "Section D—Zoology and Botany, including Physiology" (see p. xxxvi). The Section being then vacant was assigned in 1851 to Geography.

Date and Place	Presidents	Secretaries
1858. Leeds	Sir R. I. Murchison, G C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen..	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford.	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S.........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S.........	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P, K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, C. R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S, F.G.S.	H.W.Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	Clements R. Markham, A. Buchan, J. H. Thomas, A. Keith Johnston.
1872. Brighton ...	Francis Galton, F.R.S.........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast.	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol......	Lieut. - General Strachey, R.E., C S.I., F.R.S., F.R.G.S., F.L.S., F.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. Oliphant Wood.
*1877. Plymouth...	Adm. Sir E Ommanney, C.B, F.R.S., F.R.G.S., F.R.A.S.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S. L. & E.	John Coles, E. C. Rye.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

Date and Place	Presidents	Secretaries
	SECTION F.—STATISTICS.	
1835. Dublin......	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol......	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon.........	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.........	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork...... ..	Sir C. Lemon, Bart, M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev T. L. Shapcott.
1847. Oxford... ..	Travers Twiss, D.C.L., F.R S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison
1848. Swansea ...	J. H. Vivian, M.P., F.R.S.	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull.........	James Heywood, M.P., F.R.S.	Edward Cheshire, Wm. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.
	SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.	
1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines..................	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford......	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath.........	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers...........	R. Birkin, jun., Prof. Leone Levi, E. Macrory.

Date and Place	Presidents	Secretaries
1867. Dundee	M. E. Grant Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	Edmund Macrory, Frederick Purdy, Charles T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, Frank P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres.S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843 Cork	Prof. J. Macneill, M.R.I.A ...	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Professor Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Professor Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robert Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S.........	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool...	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, jun., H. M. Jeffery.
1857. Dublin	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.

Date and Place	Presidents	Secretaries
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	Wm. Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath.........	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. A. Tarbottom.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S..........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast......	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin......	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.

List of Evening Lectures.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S.......	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison..................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson.....................	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G. B. Airy, F.R.S., Astron. Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.

Date and Place	Lecturer	Subject of Discourse
1846. Southampton—*cont.*	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G.B.Airy, F.R.S., Astron. Royal	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S.......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S.	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.

Date and Place	Lecturer	Subject of Discourse
1865. Birmingham	J. Beete Jukes, F.R.S.	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S. ...	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S.............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S....	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S................	Some recent investigations and applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilization.
1872. Brighton ...	Prof. P. Martin Duncan, M.D., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarized Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	The Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S.............	The new Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.

Lectures to the Operative Classes.

1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B., R.N.	A Journey through Africa.
1877. Plymouth...	W. H. Preece	Telegraphy and the Telephone.

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L.	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S.	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S.	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.......	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne ...	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S.	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne	The Duke of Northumberland	...	...
1839, Aug. 26 ...	Birmingham.........	The Rev. W. Vernon Harcourt	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton......	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.......	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D. ...	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart......	314	18
1848, Aug. 9 ...	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12 ...	Birmingham.........	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2 ..	Ipswich...............	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3 ...	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S. ...	194	33
1856, Aug. 6 ...	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds..................	Richard Owen, M.D., D.C.L....	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. the Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A. ..	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1 ...	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6 ...	Birmingham.........	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22 ...	Nottingham.........	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee...............	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18 ...	Exeter	Prof. G. G. Stokes, D.C.L......	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2 ...	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S. ...	245	36
1873, Sept. 17 ...	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19 ...	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25 ...	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6 ...	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15 ...	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14 ...	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total			
						£ s. d.	£ s. d.	
...	...	...	...	...	353	....	....	1831
...	...	...	...	...	...	....	....	1832
...	...	...	...	...	900	....	....	1833
...	...	...	...	...	1298	....	20 0 0	1834
...	...	...	...	...	...	....	167 0 0	1835
...	...	...	...	...	1350	....	435 0 0	1836
...	...	...	...	...	1840	....	922 12 6	1837
...	...	...	1100*	...	2400	....	932 2 2	1838
...	...	...	...	34	1438	....	1595 11 0	1839
...	...	...	...	40	1353	....	1546 16 4	1840
46	317	...	60*	...	891	....	1235 10 11	1841
75	376	33†	331*	28	1315	....	1449 17 8	1842
71	185	...	160	...	...	....	1565 10 2	1843
45	190	9†	260	...	...	....	981 12 8	1844
94	22	407	172	35	1079	....	831 9 9	1845
65	39	270	196	36	857	....	685 16 0	1846
197	40	495	203	53	1320	....	208 5 4	1847
54	25	376	197	15	819	707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878

* Ladies were not admitted by purchased Tickets until 1843.
† Tickets of Admission to Sections only. ‡ Including Ladies.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from August 14, 1877 (commencement of PLYMOUTH Meeting), to August 14, 1878. Not including receipts at Dublin Meeting.

RECEIPTS.

	£	s.	d.
To Balance from last Account, Plymouth Meeting	1735	14	11
Received for Life Compositions at Plymouth Meeting and since	268	0	0
„ Annual Subscriptions ditto ditto	656	4	3
„ Associates' Tickets ditto ditto	446	0	0
„ Ladies' Tickets ditto ditto	283	0	0
„ Dividends on Stock	236	0	0
„ Sale of Publications, Vol. XVL. Glasgow	66	5	6
„ Ditto Sundries	49	1	1
Sundry small sums for Transmission of Papers to Members during Plymouth Meeting, Donations, &c.	6	2	6
Interest on Deposit at London and Westminster Bank	31	11	1
Returned by Dr. Farr, of the "Anthropometric Committee," as unexpended balance of grant	16	8	10
	£3794	8	2

WARREN DE LA RUE, G. CAREY FOSTER, W. H. FLOWER } *Auditors.*

December 3, 1878.

PAYMENTS.

	£	s.	d.	£	s.	d.
Paid Expenses of Plymouth Meeting, also Sundry Printing, Binding, Advertising, and Incidental Expenses				416	17	4
„ Printing, Engraving, and Binding Report of 46th Meeting, Vol. XLV. (Glasgow)				669	1	6
„ Salaries (1 year)				545	0	0
„ Rent and Office Expenses (Albemarle Street—1 year)				104	5	0
„ Expenses of "Committee of Boilers" at Plymouth				16	6	10
„ Grants made at Plymouth Meeting:—						
Exploration of Settle Caves	100	0	0			
Geological Record	100	0	0			
Investigation of Pulse Phenomena by means of Siphon Recorder	10	0	0			
Zoological Station at Naples	75	0	0			
Investigation of Underground Waters	15	0	0			
Transmission of Electrical Impulses through Nerve Structure	30	0	0			
Calculation of Factor Table of Four Million	100	0	0			
Anthropometric Committee	66	0	0			
Chemical Composition and Structure of less known Alkaloids	25	0	0			
Exploration of Kent's Cavern	50	0	0			
Zoological Record	100	0	0			
Fermanagh Caves Exploration	15	0	0			
Thermal Conductivity of Rocks	4	16	6			
Luminous Meteors	10	0	0			
Ancient Earthworks	25	0	0			
				725	16	6
At London and Westminster Bank on Deposit Account	£800	0	0			
„ Current Account	£423	6	6			
In hands of Assistant to General Treasurer	£93	14	6			
				1317	1	0
				£3794	8	2

A. W. WILLIAMSON.

August 14, 1878.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE DUBLIN MEETING.

SECTION A.—MATHEMATICS AND PHYSICS.

President. — Rev. Professor Salmon, D.D., D.C.L., LL.D., F.R.S., M.R.I.A.

Vice-Presidents.—Professor R. S. Ball, LL.D., F.R.S.; Rev. Professor S Haughton, LL.D., F.R.S.; Professor Henry Hennessy, F.R.S., M.R.I.A; Dr. T. A. Hirst, F.R.S.; General Menabrea; Rev. Dr. Molloy, M.R.I.A.; Rev. Professor S. J. Perry, F.R.S.; Professor John Purser, M.R.I.A.; Professor H. J. S. Smith, M.A., LL.D., F.R.S.; G. Johnstone Stoney, M.A., F.R.S., M.R.I.A.; Professor J. J. Sylvester, LL.D., F.R.S.; Sir William Thomson, M.A., LL.D., F.R.S.; Rev. Professor R. Townsend, F.R.S., M.R.I.A.

Secretaries.—Professor John Casey, LL.D., F.R.S., M.R.I.A.; G. F. Fitzgerald, M.A., F.T.C.D., M.R.I.A.; J. W. L. Glaisher, M.A., F.R.S.; Oliver J. Lodge, D.Sc.

SECTION B.—CHEMISTRY AND MINERALOGY, INCLUDING THEIR APPLICATIONS TO AGRICULTURE AND THE ARTS.

President.—Professor Maxwell Simpson, M.D., F.R.S., F.C S.

Vice-Presidents.—Professor Apjohn, F.R.S., F.C.S.; Wm. Crooker, F.R.S.; Professor Dewar, F.R.S.; Dr. J. H. Gladstone, F.R.S.; Sir R. Kane, F.R.S.; Dr. Longstaff, F.C.S.; Professor J. Emerson Reynolds, M.D., F.C.S., M.R.I.A.; Professor Roscoe, F.R.S.; Professor Rowney, F.C.S.; Professor A. W. Williamson, F.R.S.

Secretaries.—W. Chandler Roberts, F.R.S.; J. M. Thomson, F.C.S.; C. R. Tichborne, M.D.; T. Wills, F.C.S.

SECTION C.—GEOLOGY.

President.—John Evans, D.C.L., F.R.S., F.S.A., F.G.S.

Vice-Presidents.—Rev. Maxwell Close, F.G.S.; Professor W. Boyd Dawkins, M.A., F.R.S.; Sir R. Griffith, Bart., LL.D.; Rev. Professor Haughton, LL.D., F.R.S.; Professor T. M'K. Hughes, M.A., F.R.S.; Professor Hull, M.A., F.R.S.; J. Gwyn Jeffreys, LL.D., F.R.S.; W. Pengelly, F.R.S.; H. C. Sorby, F.R.S., Pres. G.S.

Secretaries.—E. T. Hardman, F.C.S.; Professor J. O'Reilly, C.E., M.R.I.A; R. H. Tiddeman, M.A., F.G.S.

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Secretaries.—John Coles, F.R.G.S., Curator of the Map Collection R.G.S.; E. C. Rye, F.Z.S., Librarian R.G.S.

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The Right Hon. LORD O'HAGAN, M.R.I.A.
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The MASTER CUTLER.
Professor T. H. HUXLEY, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S.
Professor W. ODLING, M.B., F.R.S., F.C.S.

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H. CLIFTON SORBY, Esq., F.R.S., F.G.S.
J. F. MOSS, Esq.

LOCAL TREASURER FOR THE MEETING AT SHEFFIELD.

HENRY STEPHENSON, Esq.

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ROLLESTON, Professor G., F.R.S.
ROSCOE, Professor H. E., F.R.S.
RUSSELL, Dr. W. J., F.R.S.
SANDERSON, Prof. J. S. BURDON, F.R.S.
SMYTH, WARINGTON W., Esq., F.R.S.

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PHILIP LUTLEY SCLATER, Esq., M.A., Ph.D., F.R.S., F.L.S., 11 Hanover Square, London, W.

ASSISTANT SECRETARY.

J. E. H. GORDON, Esq., B.A.

GENERAL TREASURER.

Professor A. W. WILLIAMSON, Ph.D., F.R.S., F.C.S., University College, London, W.C.

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The Trustees, the President and President Elect, the Presidents of former years, the Vice-Presidents and Vice-Presidents Elect, the General Secretaries for the present and former years, the late Assistant General Secretary, the General Treasurers for the present and former years, and the Local Treasurer and Secretaries for the ensuing Meeting.

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Report of the Council for the Year 1877-78, *presented to the General Committee at Dublin on Wednesday, August* 14, 1878.

The Council have received Reports during the past year from the General Treasurer, and his account for the year will be laid before the General Committee this day.

The following Resolution was referred by the General Committee at Plymouth to the Council for consideration, and for action, if it should seem desirable, viz.:—

> "That the question of the appointment of a Committee, consisting of Mr. F. J. Bramwell, Mr. J. F. Bateman, Mr. G. F. Deacon, Mr. Rogers Field, Captain Douglas Galton, Mr. R. B. Grantham, Mr. Baldwin Latham, Mr. C. W. Merrifield, and Mr. G. J. Symons, for carrying on Observations on the Rainfall of the British Isles, be referred to the Council for consideration, and action, if it seem desirable; and that the sum of 150*l.* be placed at the disposal of the Council for the purpose."

The Council having considered the Resolution, and having placed themselves in communication with Mr. Symons, decided that it would not be desirable to appoint the proposed Committee, as, under the system organised by Mr. Symons, the grant which had been made in former years by the Association could be discontinued without detriment to science.

The General Committee adopted last year certain modifications of the Rules of the Association, which had for their object the exclusion of unscientific or other unsuitable papers and discussions from the sectional proceedings of the Association: and the Council have, during the past year, further considered this question.

The Council are of opinion that the existing Rules of the Association, with the additions hereto subjoined, will afford, if carried out in their integrity, a sufficient guarantee for the exclusion of unscientific and unsuitable papers:—

1.—That the appointment of Sectional Presidents, Vice-Presidents, and Secretaries be made either a year in advance or at such early period as the Council may find practicable.

2.—That no paper received after the commencement of the Meeting shall be read, unless recommended by the Committee of the Section, after it has been referred and reported upon.

At the Meeting of the Association held at Plymouth, invitations were laid before the General Committee, for the year 1879, from Swansea and from Nottingham.

The invitation from the Mayor and Town Council of Nottingham to meet in that town in 1879 was accepted; and it was understood that it would be preferable to defer the meeting at Swansea until 1880.

In the course of the Autumn the Council received a communication from the Town Council of Nottingham, to the effect that it would not be convenient for them to receive the Association in 1879.

The Mayor and Town Council of Sheffield have intimated to the Council that they are desirous of receiving the Association in 1879; and invitations from the Mayor and Town Council of Sheffield, and from the Scientific Bodies in that town, will be laid before the General Committee in due course.

The invitation from Swansea for 1880, received last year, will be renewed on the present occasion; and it will be in the recollection of the General Committee that an invitation was received last year from York, proposing that the fiftieth anniversary of the Association be held in that city in 1881.

In accordance with a recommendation made by the Committee of Section D. at Plymouth, and adopted by the General Committee, the "Rules for Zoological Nomenclature," drawn up in 1842 at the instance of the Association, have been reprinted and published.

The following men of science, who have attended meetings of the Association, have been elected Corresponding Members:—

Professor H. L. F. Helmholtz, Berlin.
Dr. H. Kronecker, Berlin.
M. Akin Kàroly, Pesth.
Dr. Lindeman, Bremen.
Professor Moissonet, Paris.

The Council have nominated the Duke of Abercorn, K.G., and the Earl of Enniskillen, F.R.S., as Vice-Presidents of the present Meeting; and they submit these nominations for confirmation by the General Committee.

The following are the names of the Members of Council for the past year, who, in accordance with the regulations, are not eligible for re-election this year, viz.:—

Mr. De La Rue.
Professor Maxwell.
Professor H. J. S. Smith.
Lord Houghton.
Colonel Grant.

The Council recommend the re-election of the ordinary Members of Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list:—

Abel, F. A., Esq., F.R.S.
*Adams, Prof. W. G., F.R.S.
Barlow, W. H., Esq., F.R.S.
Bramwell, F. J., Esq., F.R.S.
Cayley, Prof., F.R.S.
Evans, J., Esq., F.R.S.
*Evans, Captain, F.R.S.
Farr, Dr. W., F.R.S.
Foster, Prof. G. C., F.R.S.
Froude, W., Esq., F.R.S.
*Glaisher, J. W. L., Esq., F.R.S.
Heywood, J., Esq., F.R.S.
Huggins, W., Esq., F.R.S.
*Lefevre, George Shaw, Esq., M.P.
Maskelyne, Prof. N. S., F.R.S.
Newton, Prof. A., F.R.S.
Ommanney, Adm. Sir E., F.R.S.
Pengelly, W., Esq., F.R.S.
Prestwich, Prof. J., F.R.S.
*Rayleigh, Lord, F.R.S.
Rolleston, Prof., F.R.S.
Roscoe, Prof., F.R.S.
Russell, Dr. W. J., F.R.S.
Sanderson, Prof. J. B., F.R.S.
Smyth, Warington W., Esq., F.R.S.

The Council regret that pressing engagements compel Mr. Griffith to withdraw finally from the position of Assistant-General Secretary after the present meeting of the Association, and take this opportunity of expressing their high estimation of the value of the services which Mr. Griffith has rendered to the Association during a period of sixteen years, and of the serious loss which his retirement will occasion to the Council and to the Association. Mr. Griffith remains an ex-officio Member of Council, as a former general officer, so that the Council trust they may still retain the benefit of his experience.

In accordance with the Report of last year, the Council will propose to the General Committee that the post of Assistant Secretary be filled by the election of Mr. J. E. H. Gordon.

Recommendations adopted by the General Committee at the Dublin Meeting in August 1878.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Involving Grants of Money.

That the Committee, consisting of Professor Cayley, Professor G. G. Stokes, Professor H. J. S. Smith, Professor Sir William Thomson, Mr. James Glaisher, and Mr. J. W. L. Glaisher (Secretary), be reappointed; and that the sum of 150*l.* be placed at their disposal for the purpose of calculating Factor Tables of the fifth and sixth millions.

That a Committee, consisting of Professor Sylvester (Secretary) and Professor Cayley, be appointed for the purpose of calculating Tables of the Fundamental Invariants of Algebraic Forms; and that the sum of 50*l.* be placed at their disposal for the purpose.

That the Committee, consisting of Professor G Forbes (Secretary), Professor Sir William Thomson, and Professor J. D. Everett, for the purpose of making certain observations in India, and observations on Atmospheric Electricity at Madeira, be reappointed; and that the grant of 15*l.* that has lapsed be renewed.

That the Rev. Dr. Haughton and Mr. B. Williamson be a Committee for the calculation of Tables of Sun-heat Coefficients; that Mr. B. Williamson be the Secretary, and that the sum of 30*l.* be placed at their disposal for the purpose.

That the Committee, consisting of Dr. Joule (Secretary), Professor Sir William Thomson, Professor Tait, Professor Balfour Stewart, and Professor J. Clerk Maxwell, for effecting the Determination of the Mechanical Equivalent of Heat be reappointed; and that the grant of 65*l.* that has lapsed be renewed.

That a Committee, consisting of Professor G. Forbes (Secretary), Professor W. G. Adams, and Mr. W. E. Ayrton, be appointed for the purpose of improving an instrument for detecting the presence of Fire-damp in Mines; and that the sum of 30*l.* be placed at their disposal for the purpose.

That Mr. W. E. Ayrton (Secretary), Dr. O. J. Lodge, and Mr. J. E. H. Gordon be appointed a Committee for accurately measuring the specific

inductive capacity of a good Sprengel Vacuum; and that the sum of 40*l*. be placed at their disposal for the purpose.

That the Committee, consisting of Mr. James Glaisher (Secretary), Mr. R. P. Greg, Mr. Charles Brooke, Dr. Flight, and Professor A. S. Herschel, on Luminous Meteors be reappointed; and that the sum of 20*l*. be placed at their disposal.

That a Committee, consisting of Mr. David Gill (Secretary), Professor G. Forbes, Mr. Howard Grubb, and Mr. C. H. Gimingham (with power to add to their number), be appointed to consider the question of improvements in Astronomical Clocks; and that the sum of 30*l*. be placed at their disposal for the purpose.

That Mr. W. Chandler Roberts, Dr. C. R. A. Wright, and Mr. A. P. Luff be a Committee for the purpose of investigating the Chemical Composition and Structure of some of the less-known Alkaloids; that Dr. Wright be the Secretary, and that the sum of 25*l*. be placed at their disposal for the purpose.

That Dr. Wallace, Professor Dittmarr, and Mr. T. Wills be a Committee for the purpose of reporting on the best means for the development of Light from Coal-gas of different qualities; that Mr. Wills be the Secretary, and that the sum of 10*l*. be placed at their disposal for the purpose.

That Professor W. G. Adams, Mr. John M. Thomson, Mr. W. N. Hartley, and Mr. James T. Bottomley be a Committee for the purpose of investigating the law of the "Electrolysis of mixed metallic solutions and solutions of compound salts;" that Mr. John M. Thomson be the Secretary, and that the sum of 25*l*. be placed at their disposal for the purpose.

That Mr. John Evans, Sir John Lubbock, Major-General Lane Fox, Mr. George Busk, Professor Boyd Dawkins, Mr. Pengelly, and Mr. A. W. Franks be a Committee for the purpose of exploring Caves in Borneo; that Mr. Evans be the Secretary, and that the sum of 50*l*. be placed at their disposal for the purpose.

That Professor Hull, the Rev. H. W. Crosskey, Captain D. Galton, Mr. Glaisher, Mr. G. A. Lebour, Mr. W. Molyneux, Mr. Morton, Mr. Pengelly, Professor Prestwich, Mr. Plant, Mr. Mellard Reade, Mr. Roberts, Mr. W. Whitaker, and Mr. De Rance be a Committee for the purpose of investigating the Circulation of the Underground Waters in the Permian, New Red Sandstone, and Jurassic Formations of England, and the Quantity and Character of the Water supplied to towns and districts from those formations; that Mr. De Rance be the Secretary, and that the sum of 15*l*. be placed at their disposal for the purpose.

That Mr. Godwin-Austen, Professor Prestwich, Mr. Davidson, Mr. Etheridge, Mr. Willett, and Mr. Topley be a Committee for the purpose of assisting the Kentish Boring Exploration; that Mr. Willett and Mr. Topley be the Secretaries, and that the sum of 100*l*. be placed at their disposal for the purpose.

That Dr. J. Evans, Sir John Lubbock, Mr. E. Vivian, Mr. W. Pengelly, Mr. G. Busk, Professor W. B. Dawkins, Mr. W. A. Sandford, and Mr. J. E. Lee be a Committee for the purpose of continuing the Exploration of Kent's Cavern, Torquay; that Mr. Pengelly be the Secretary, and that the sum of 100*l*. be placed at their disposal for the purpose.

That Dr. J. Evans, the Rev. T. G. Bonney, Mr. W. Carruthers, Mr. F. Drew, Mr. R. Etheridge, jun., Mr. G. A. Lebour, Professor L. C. Miall, Professor H. A. Nicholson, Mr. F. W. Rudler, Mr. E. B. Tawney, Mr. W.

Topley, and Mr. W. Whitaker be a Committee for the purpose of carrying on the Geological Record; that Mr. Whitaker be the Secretary, and that the sum of 100*l*. be placed at their disposal for the purpose.

That the Rev. Dr. Haughton, Professor Leith Adams, Professor Barrett, Mr. Hardman, and Dr. Macalister be a Committee for the purpose of exploring the Fermanagh Caves; that Dr. Macalister be the Secretary, and that the sum of 5*l*. be placed at their disposal for the purpose.

That the Rev. Maxwell Close, Professor W. C. Williamson, and Mr. W. H. Baily be a Committee for the purpose of collecting and reporting on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland; that Mr. W. H. Baily be the Secretary, and that the sum of 20*l*. be placed at their disposal for the purpose.

That Mr. Spence Bate and Mr. J. Brooking Rowe be a Committee for the purpose of exploring the Marine Zoology of South Devon; that Mr. Spence Bate be the Secretary, and that the sum of 20*l*. be placed at their disposal for the purpose.

That Mr. Stainton, Sir J. Lubbock, and Mr. E. C. Rye be reappointed a Committee for the purpose of continuing a Record of Zoological Literature; that Mr. Stainton be the Secretary, and that the sum of 100*l*. be placed at their disposal for the purpose.

That Dr. M. Foster, Professor Rolleston, Mr. Dew-Smith, Professor Huxley, Dr. Carpenter, Dr. Gwyn Jeffreys, Mr. Sclater, Mr. F. M. Balfour, Sir C. Wyville Thomson, and Professor Ray Lankester be reappointed a Committee for the purpose of arranging with Dr. Dohrn for the occupation of a table at the Zoological Station at Naples during the ensuing year; that Mr. Dew-Smith be the Secretary, and that the sum of 75*l*. be placed at their disposal for the purpose.

That Sir Victor Brooke, Professor Flower, and Mr. Sclater be a Committee for the purpose of assisting Professor Leith Adams in preparing Plates illustrating a Monograph on the Mammoth; that Sir Victor Brooke be the Secretary, and that the sum of 17*l*. be placed at their disposal for the purpose.

That Mr. Sclater, Dr. G. Hartlaub, Sir Joseph Hooker, Captain J. W. Hunter, and Professor Flower be a Committee for the purpose of taking steps for the investigation of the Natural History of Socotra; that Mr. Sclater be the Secretary, and that the sum of 100*l*. be placed at their disposal for the purpose.

That Professor Rolleston, Major-General Lane Fox, Dr. John Evans, Professor Boyd Dawkins, and Mr. Edward Laws be a Committee for the purpose of exploring certain Bone Caves in South Wales; that Professor Rolleston be the Secretary, and that the sum of 50*l*. be placed at their disposal for the purpose.

That Major-General Lane Fox, Professor Rolleston, and Mr. F. G. H. Price be a Committee for the purpose of exploring Ancient Earthworks; that Major-General Lane Fox be the Secretary, and that the sum of 25*l*. be placed at their disposal for the purpose.

That Major-General Lane Fox, Mr. William James Knowles, Dr. Leith Adams, and the Rev. Dr. Grainger be a Committee for the purpose of conducting Excavations at Portstewart and elsewhere in the North of Ireland; that Mr. Knowles be the Secretary, and that the sum of 15*l*. be placed at their disposal for the purpose.

That Dr. Farr, Dr. Beddoe, Mr. Brabrook, Sir George Campbell, Mr. F. P. Fellows, Major-General Lane Fox, Mr. Francis Galton, Mr. Park

Harrison, Mr. James Heywood, Mr. P. Hallett, Professor Leone Levi, Sir Rawson Rawson, Professor Rolleston, and Mr. Charles Roberts be a Committee for the purpose of continuing the collection of observations on the Systematic Examination of Heights, Weights, &c., of Human Beings in the British Empire, and the publication of photographs of the typical Races of the Empire; that Mr. E. W. Brabrook be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That the Committee, consisting of Professor Sir William Thomson, Major-General Strachey, Captain Douglas Galton, Mr. G. F. Deacon, Mr. Rogers Field, Mr. E. Roberts, and Mr. J. N. Shoolbred, be reappointed for the purpose of considering the Datum-level of the Ordnance Survey of Great Britain, with a view to its establishment on a surer foundation than hitherto, and for the tabulation and comparison of other Datum-marks; that Mr. James N. Shoolbred be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That the Committee on Instruments for Measuring the Speed of Ships, consisting of Mr. W. Froude, Mr. F. J. Bramwell, Mr. A. E. Fletcher, the Rev. E. L. Berthon, Mr. James R. Napier, Mr. C. W. Merrifield, Dr. C. W. Siemens, Mr. H. M. Brunel, Mr. J. N. Shoolbred, Professor James Thomson, and Professor Sir William Thomson, be reappointed; that Mr. James N. Shoolbred be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That the Committee, consisting of Mr. James R. Napier, Sir William Thomson, Mr. William Froude, Professor Osborne Reynolds, and Mr. J. T. Bottomley, for the purpose of making experiments and of reporting on the effect of the Propeller on the turning of Steam-vessels be reappointed (with power to communicate with the Government); that Professor Osborne Reynolds be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That the Committee, consisting of Professor Sir William Thomson, Dr. Merrifield, Mr. W. Froude, Professor Osborne Reynolds, Captain Douglas Galton, and Mr. James N. Shoolbred (with power to add to their number), be reappointed for the purpose of obtaining information respecting the Phenomena of the stationary Tides in the English Channel and in the North Sea, and of representing to the Government of Portugal and the Governor of Madeira that in the opinion of the British Association tidal observations at Madeira or other islands in the North Atlantic Ocean would be very valuable, with the view to the advancement of our knowledge of the tides in the Atlantic Ocean; that Mr. James N. Shoolbred be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

Applications for Reports and Researches not involving Grants of Money.

That the Committee, consisting of Professor Sir William Thomson (Secretary), Professor Clerk Maxwell, Professor Tait, Dr. C. W. Siemens, Mr. F. J. Bramwell, Mr. W. Froude, and Mr. J. T. Bottomley, for continuing secular experiments upon the Elasticity of Wires be reappointed.

That the Committee, consisting of Dr. W. Huggins (Secretary), Mr. J. N. Lockyer, Professor J. Emerson Reynolds, Mr. G. J. Stoney, Mr. W. Spottiswoode, Dr. De La Rue, and Dr. W. M. Watts, for the purpose of preparing and printing Tables of Oscillation-frequencies be reappointed.

That the Committee, consisting of Professor Everett (Secretary),

Professor Sir William Thomson, Professor J. Clerk Maxwell, Mr. G. J. Symons, Professor Ramsay, Professor Geikie, Mr. J. Glaisher, Mr. Pengelly, Professor Edward Hull, Professor Ansted, Dr. Clement Le Neve Foster, Professor A. S. Herschel, Mr. G. A. Lebour, Mr. A. B. Wynne, Mr. Galloway, Mr. Joseph Dickinson, and Mr. G. F. Deacon, on Underground Temperature be reappointed.

That the Committee consisting of Professor G. C. Foster, Professor W. G. Adams, Professor R. B. Clifton, Professor Cayley, Professor J. D. Everett, Professor Clerk Maxwell, Lord Rayleigh, Professor G. G. Stokes, Professor Balfour Stewart, Mr. Spottiswoode, and Professor P. G. Tait be reappointed, for the purpose of endeavouring to procure Reports on the progress of the chief branches of Mathematics and Physics; and that Professor G. Carey Foster be the Secretary.

That Mr. C. W. Merrifield be requested to report on the present state of knowledge of the Application of Quadratures and Interpolation to Actual Data.

That the Committee, consisting of Mr. Spottiswoode, Professor G. G. Stokes, Professor Cayley, Professor H. J. S. Smith, Professor Sir William Thomson, Professor Henrici, Lord Rayleigh, and Mr. J. W. L. Glaisher (Secretary), on Mathematical Notation and Printing be reappointed.

That the Committee, consisting of Professor Sir William Thomson (Secretary). Professor Tait, Professor Grant, Dr. Siemens, Professor Purser, Professor G. Forbes, and Mr. David Gill, for the Measurement of the Lunar Disturbance of Gravity be reappointed.

That a Committee, consisting of Captain Abney (Secretary), Professor W. G. Adams, and Professor G. C. Foster, be appointed to carry out an investigation for the purpose of fixing a Standard of White Light.

That Professor A. S. Herschel, Mr. J. T. Dunn, and Mr. G. A. Lebour be reappointed a Committee for the purpose of making experiments on the Thermal Conductivities of certain rocks; and that Professor Herschel be the Secretary.

That Mr. R. J. Moss, Professor Boyd Dawkins, Professor Hull, Dr. Moss, R.N., Mr. Pengelly, Dr. Leith Adams, Professor O'Reilly, and Mr. John Evans be a Committee for the purpose of obtaining information with regard to the mode of occurrence of the remains of *Cervus Megaceros* in Ireland; and that Mr. R. J. Moss be the Secretary.

That Professor Prestwich, Professor Harkness, Professor Hughes, Professor W. Boyd Dawkins, the Rev. H. W. Crosskey, Professor L. C. Miall, Messrs. G. H. Morton, D. Mackintosh, R. H. Tiddeman, J. E. Lee, J. Plant, W. Pengelly, Dr. Deane, Mr. C. J. Woodward, and Mr. Molyneux be a Committee for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation; and that the Rev. H. W. Crosskey be the Secretary.

That Mr. C. Spence Bate be requested to continue his Report "On the present state of our knowledge of the Crustacea."

That Sir George Campbell, M.P., Lord O'Hagan, Mr. Morley, M.P., Mr. Chadwick, M.P., Mr. Shaw Lefevre, M.P. Mr. Heywood, Mr. Hallett, Professor Jevons, Dr. Farr, Mr. Stephen Bourne, Mr. Hammick, Professor Leone Levi, Professor J. K. Ingram, Dr. Hancock, and Mr. J. T. Pim (with power to add to their number) be a Committee to continue the researches into the Incidence of Direct Taxation, with special reference to

Probate, Legacy, and Succession Duty, and the Assessed Taxes; and that Dr. Hancock be the Secretary.

That the Committee consisting of Dr. A. W. Williamson, Professor Sir William Thomson, Mr. Bramwell, Mr. St. John Vincent Day, Dr. C. W. Siemens, Mr. C. W. Merrifield, Dr. Neilson Hancock, Professor Abel, Mr. J. R. Napier, Captain Douglas Galton, Mr. Newmarch, Mr. E. H. Carbutt, Mr. Macrory, and Mr. H. Trueman Wood be reappointed, for the purpose of watching and reporting to the Council on Patent Legislation; and that Mr. F. J. Bramwell be the Secretary.

Communications ordered to be printed in extenso *in the Annual Report of the Association.*

That Dr. Dobson's paper "On the Geographical Distribution of the Chiroptera" be printed *in extenso* among the Reports.

That the paper by Mr. Bindon B. Stoney, on "Recent Improvements in the Port of Dublin," be printed *in extenso* among the Reports, with such plans and diagrams as may be deemed necessary by the Council.

Resolutions referred to the Council for consideration and action if it seem desirable.

That the attention of the Council of the Association be called to the fact that the recommendations of the Royal Commission on Science have been altogether disregarded in the Act lately passed to enable the Trustees of the British Museum to remove the Natural History Collection to South Kensington, and that the Council be requested to take such steps in the matter as they shall think most desirable in the interests of science.

That the question of the reappointment of the Committee, consisting of the Rev. H. F. Barnes, Mr. Spence Bate, Mr. H. E. Dresser (Secretary), Mr. J. E. Harting, Dr. Gwyn Jeffreys, Professor Newton, the Rev. Canon Tristram, and Mr. G. Shaw Lefevre, for the purpose of inquiring into the possibility of establishing a "close time," for the protection of indigenous animals, be referred to the Council for consideration; and that the Council be empowered to take such steps in the matter as they shall think most desirable in the interests of science.

That the question of the appointment of a Committee, consisting of Mr. James Dillon, Mr. Edward Easton, Mr. P. Le Neve Foster, Captain Douglas Galton, Mr. T. Hawksley, Sir John Hawkshaw, Professor Hull, Mr. Robert Manning, Professor Prestwich, Professor Ramsay, Mr. C. E. De Rance, the Earl of Rosse, Mr. W. Shelford, Mr. J. N. Shoolbred, Mr. John Smyth, jun., Mr. G. J. Symons, and Mr. A. T. Atchison (Secretary), for the purpose of conferring with the Council as to the advisability of urging Government to take immediate action to procure unity of control of each of our principal river basins, be referred to the Council for consideration and action if it seem desirable.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Dublin Meeting in August 1878. *The Names of the Members who would be entitled to call on the General Treasurer for the respective Grants are prefixed.*

Mathematics and Physics.

	£	s.	d.
*Cayley, Prof.—Calculation of Factor Tables for the Fifth and Sixth Millions	150	0	0
Sylvester, Prof.—Tables of Fundamental Invariants of Algebraic Forms	50	0	0
*Forbes, Prof. G.—Observation of Atmospheric Electricity at Madeira (renewed)	15	0	0
Haughton, Rev. Prof.—Tables of Sun-heat Co-efficients ...	30	0	0
*Joule, Dr.—Determination of the Mechanical Equivalent of Heat (renewed)	65	0	0
Forbes, Prof. G.—Instrument for Detecting the Presence of Fire-damp in Mines	30	0	0
Ayrton, Mr. W. E.—Specific Inductive Capacity of a good Sprengel Vacuum	40	0	0
Glaisher, Mr.—Luminous Meteors	20	0	0
Gill, Mr. D.—Improvements in Astronomical Clocks	30	0	0

Chemistry.

	£	s.	d.
*Roberts, Mr. Chandler.—Composition and Structure of some of the less-known Alkaloids	25	0	0
*Wallace, Dr.—Development of Light from Coal-Gas of different Qualities	10	0	0
Adams, Prof. W. G.—Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Evans, Dr. J.—Exploration of Caves in Borneo	50	0	0
*Hull, Prof.—Circulation of Underground Waters	15	0	0
*Godwin-Austen, Mr.—Kentish Boring Exploration (renewed)	100	0	0
*Evans, Dr. J.—Kent's Cavern Exploration	100	0	0
*Evans, Dr. J.—Record of the Progress of Geology	100	0	0
*Haughton, Rev. Dr.—Fermanagh Caves Exploration	5	0	0
Close, Rev. Maxwell.—Miocene Flora of the Basalt of the North of Ireland	20	0	0
Carried forward	880	0	0

* Reappointed.

Biology.

	£	s.	d.
Brought forward	880	0	0
Bate, Mr. Spence C.—Marine Zoology of South Devon	20	0	0
*Stainton, Mr.—Record of Zoological Literature	100	0	0
*Foster, Dr. M.—Table at the Zoological Station, Naples	75	0	0
Brooke, Sir Victor, Bart.—Illustrations for a Monograph on the Mammoth	17	0	0
Sclater, Mr.—Natural History of Socotra	100	0	0
*Rolleston, Prof.—Exploration of Bone-caves in South Wales (partly renewed)	50	0	0
*Fox, General Lane.—Exploration of Ancient Earthworks	25	0	0
Fox, General Lane.—Excavation at Portstewart and elsewhere in the North of Ireland	15	0	0

Statistics and Economic Science.

*Farr, Dr.—Anthropometric Committee	50	0	0

Mechanics.

*Thomson, Sir W.—Datum-level of the Ordnance Survey	10	0	0
*Froude, Mr. W.—Instruments for measuring the Speed of Ships (renewed)	50	0	0
*Napier, Mr. J. R.—Steering of Screw Steamers	10	0	0
*Thomson, Sir W.—Tidal Observations in the English Channel	10	0	0
	£1412	0	0

* Reappointed.

The Annual Meeting in 1879.

The Meeting at Sheffield will commence on Wednesday, August 20, 1879.

Place of Meeting in 1880.

The Annual Meeting of the Association in 1880 will be held at Swansea.

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	171	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	166	16	6
Animal Secretions	10	10	0
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0

	£	s.	d.
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

	£	s.	d.
1844.			
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology......1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8
1845.			
Publications of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9
1846.			
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0
1847.			
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

	£	s.	d.
1848.			
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8
1849.			
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6
1850.			
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

	£	s.	d.
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856.			
Maintaining the Establishment at Kew Observatory:— 1854 £75 0 0; 1855 £500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£731	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0

	£	s.	d.
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0

	£	s.	d.
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance......	150	0	0
Thermo-Electric Currents ...	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory..	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal...........	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards............	100	0	0
—— Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida..........................	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory..	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland...	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee ...	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays.....................	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory..	600	0	0
Balloon Committee	100	0	0
Hydroida..........................	13	0	0
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation ...	10	0	0
Eurypterus	50	0	0
Electrical Standards............	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches...	150	0	0
Kent's Hole Excavations......	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands ...	50	0	0
Zoological Nomenclature......	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment of Kew Observatory..	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee...........	50	0	0
British Rainfall..................	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed ...	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation ...	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards...........	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast ...	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water.......................	50	0	0
Polycyanides of Organic Radicals	20	0	0

	£	s.	d.
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds.	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcon Quarries Fossils	20	0	0

	£	s.	d.
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-Embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-Lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-Lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions, &c.	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetization of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-Corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-Measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Eliptic Functions	100	0	0
Magnetization of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0

	£	s.	d.
Specific Volume of Liquids...	25	0	0
Estimation of Potash and Phosphoric Acid..............	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations ...	100	0	0
Kent's Cavern Exploration...	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record..............	100	0	0
Instructions for Travellers ...	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall..................	100	0	0
Ohm's Law........................	9	15	0
Tide Calculating Machine ...	200	0	0
Specific Volume of Liquids...	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate or Ethyl Sodaceto-acetate..........................	5	0	0
Estimation of Potash and Phosphoric Acid..............	13	0	0
Exploration of Victoria Cave, Settle	100	0	0
Geological Record..............	100	0	0
Kent's Cavern Exploration...	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland......	1	10	0
Zoological Record..............	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Zoological Station..............	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles......	13	15	0
Measuring Speed of Ships ...	10	0	0
Effect of Propeller on turning of Steam Vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acids in Minerals........................	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record..............	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpæ, Report on......	20	0	0
Mechanical Equivalent of Heat............................	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperatures	50	0	0
Settle Cave Explanation	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Elasticity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid..............	1	18	0
Geological Record..............	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c..............	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record..............	100	0	0
Investigation of Pulse Phenomena by means of Syphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters..........................	15	0	0
Transmission of Electrical Impulses through Nerve Structure........................	30	0	0
Calculation of Factor Table of Fourth Million	100	0	0
Anthropometric Committee...	66	0	0
Chemical Composition and Structure of less known Alkaloids...........	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record..............	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors..............	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

General Meetings.

On Wednesday, August 14, at 8 P.M., in the Exhibition Palace, Professor Allen Thomson, M.D., LL.D , F.R S., President, resigned the office of President to William Spottiswoode, Esq., M.A., D.C.L., LL.D., F R S , who took the Chair, and delivered an Address, for which see page 1.

On Thursday, August 15, at 8 P.M., a Soirée took place at the Royal Dublin Society's rooms.

On Friday, August 16, at 8.30 P.M , in the Exhibition Palace, G. J. Romanes, Esq., F.L.S., delivered a Discourse on "Animal Intelligence."

On Monday, August 19, at 8.30 P.M., in the Exhibition Palace, Professor Dewar, F.R.S., delivered a Discourse on "Dissociation, or Modern Ideas of Chemical Action."

On Tuesday, August 20, at 8 P.M., a Soirée took place at the Royal Irish Academy.

On Wednesday, August 21, the concluding General Meeting took place, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to Sheffield.*

* The Meeting is appointed to take place on Wednesday, August 20, 1879.

ADDRESS

OF

WILLIAM SPOTTISWOODE, Esq.,

M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S.,

PRESIDENT.

On looking back at the long array of distinguished men who both in this and in the sister countries have filled the chair of the British Association; on considering also the increased pains which have been bestowed upon, and the increased importance attaching to, the Presidential Address; it may well happen when, as on this occasion, your choice has fallen upon one outside the sphere of professional Science, that your nominee should feel unusual diffidence in accepting the post. Two considerations have however in my own case outweighed all reasons for hesitation: First, the uniform kindness which I received at the hands of the Association throughout the eight years during which I had the honour of holding another office; and, secondly, the conviction that the same goodwill which was accorded to your Treasurer would be extended to your President.

These considerations have led me to arrange my observations under two heads, viz., I propose first to offer some remarks upon the purposes and prospects of the Association with which, through your suffrages, I have been so long and so agreeably connected; and, secondly, to indulge in a few reflexions, not indeed upon the details or technical progress, but upon the external aspects and tendencies of the Science which on this occasion I have the honour to represent. The former of these subjects is perhaps trite; but as an old man is allowed to become garrulous on his own hobby, so an old officer may be pardoned for lingering about a favourite theme. And although the latter may appear somewhat unpromising, I have decided to make it one of the topics of my discourse, from the consideration that the holder of this office will generally do better by giving utterance to what has already become part of his own thought, than by gathering matter outside of its habitual range for the special occasion. For, as it seems to me, the interest (if any) of an

address consists, not so much in the multitude of things therein brought forward, as in the individuality of the mode in which they are treated.

The British Association has already entered its fifth decade. It has held its meetings, this the 48th, in twenty-eight different towns. In six cities of note, viz., York, Bristol, Newcastle-on-Tyne, Plymouth, Manchester, and Belfast, its curve of progress may be said to have a node, or point through which it has twice passed; in the five Universities of Oxford, Cambridge, Dublin, Edinburgh, and Glasgow, and in the two great commercial centres, Liverpool and Birmingham, it may similarly be said to have a triple point, or one through which it has three times passed. Of our forty-six Presidents more than half (twenty-six, in fact) have passed away; while the remainder hold important posts in Science, and in the Public Service, or in other avocations not less honourable in themselves, nor less useful to the commonwealth. And whether it be due to the salubrity of the climate or to the calm and dispassionate spirit in which Science is pursued by its votaries here, I do not pretend to say; but it is a fact that the earliest of our ex-Presidents still living, himself one of the original members of the Association, is a native of and resident in this country.

At both of our former meetings held in Dublin, in 1835 and 1857 respectively, while greatly indebted to the liberal hospitality of the citizens at large, we were, as we now are, under especial obligations to the authorities of Trinity College for placing at our disposal buildings, not only unusually spacious and convenient in themselves, but full of reminiscences calculated to awake the scientific sympathies of all who may be gathered in them. At both of those former Dublin meetings the venerable name of Lloyd figured at our head; and if long-established custom had not seemed to preclude it, I could on many accounts have wished that we had met for a third time under the same name. And although other distinguished men, such as Dr. Robinson, Professors Stokes, Tyndall, and Andrews, are similarly disqualified by having already passed the Presidential chair, while others again, such as Sir W. R. Hamilton, Dr. M'Cullagh, and Professor Jukes, are permanently lost to our ranks; still we should not have had far to seek, had we looked for a President in this fertile island itself. But as every one connected with the place of meeting partakes of the character of host towards ourselves as guests, it has been thought by our oldest and most experienced members that we should better respond to an invitation by bringing with us a President to speak as our representative than by seeking one on the spot; and we may always hope on subsequent occasions that some of our present hosts may respond to a similar call.

But leaving our past history, which will form a theme more appropriate to our jubilee meeting in 1881, at the ancient city of York, I will ask your attention to a few particulars of our actual operations.

Time was when the Royal Societies of London and Edinburgh and the Royal Irish Academy were the only representative bodies of

British Science and the only receptacles of memoirs relating thereto. But latterly, the division of labour, so general in industrial life, has operated in giving rise to special Societies, such as the Astronomical, the Linnæan, the Chemical, the Geological, the Geographical, the Statistical, the Mathematical, the Physical, and many others. To both the earlier, or more general, and the later or more special societies alike, the British Association shows resemblance and affinity. We are general in our comprehensiveness; we are special in our sectional arrangement; and in this respect we offer not only a counterpart, but to some extent a counterpoise, to the general tendency to sub-division in Science. Further still, while maintaining in their integrity all the elements of a strictly scientific body, we also include, in our character of a microcosm, and under our more social aspect, a certain freedom of treatment, and interaction of our various branches, which is scarcely possible among separate and independent societies.

The general business of our meetings consists, first, in receiving and discussing communications upon scientific subjects at the various sections into which our body is divided, with discussions thereon; secondly, in distributing, under the advice of our Committee of Recommendations, the funds arising from the subscriptions of members and associates; and thirdly, in electing a Council upon whom devolves the conduct of our affairs until the next meeting.

The communications to the sections are of two kinds, viz., papers from individuals, and reports from Committees.

As to the subject-matter of the papers, nothing which falls within the range of Natural Knowledge, as partitioned among our sections, can be considered foreign to the purposes of the Association; and even many applications of Science, when viewed in reference to their scientific basis, may properly find a place in our proceedings. So numerous, however, are the topics herein comprised, so easy the transition beyond those limits, that it has been thought necessary to confine ourselves strictly within this range, lest the introduction of other matters, however interesting to individual members, should lead to the sacrifice of more important subjects. As to the form of the communications, while it is quite true that every scientific conclusion should be based upon substantial evidence, every theory complete before being submitted for final adoption, it is not the less desirable that even tentative conclusions and hypothetical principles when supported by sufficient primâ facie evidence, and enunciated in such a manner as to be clearly apprehended, should find room for discussion at our sectional meetings. Considering, however, our limitations of time, and the varied nature of our audience, it would seem not inappropriate to suspend, mentally if not materially, over the doors of our section rooms, the Frenchman's dictum, that no scientific theory 'can be considered complete until it is so clear that it can be explained to the first man you meet in the street.'

Among the communications to the Sections, undoubtedly the most important, as a rule, are the Reports; that is to say, documents issuing from specially appointed committees, some of which have been recipients of the grants mentioned above. These Reports are in the main of two kinds, first, accounts of observations carried on for a series of years, and intended as records of information on the special subjects; such for instance have been those made by the Kew Committee, by the committees on Luminous Meteors, on British Rainfall, on the Speed of Steamships, on Underground Temperature, on the Exploration of certain Geological Caverns, &c. These investigations, frequently originating in the energy and special qualifications of an individual, but conducted under the control of a Committee, have in many cases been continued from year to year, until either the object has been fully attained, or the matter has passed into the hands of other bodies, which have thus been led to recognise an inquiry into these subjects as part and parcel of their appropriate functions. The second class is one which is perhaps even more peculiar to the Association; viz., the Reports on the progress and present state of some main topics of Science. Among these may be instanced the early Reports on Astronomy, on Optics, on the Progress of Analysis; and later, those on Electrical Resistance, and on Tides; that of Professor G. G. Stokes on Double Refraction; that of Professor H. J. Smith on the Theory of Numbers; that of Mr. Russell on Hyperelliptic Transcendents; and others. On this head Professor Carey Foster, in his address to the Mathematical and Physical Section at our meeting last year, made some excellent recommendations, to which, however, I need not at present more particularly refer, as the result of them will be duly laid before the section in the form of the report from a Committee to whom they were referred. It will be sufficient here to add that the wide extension of the Sciences in almost every branch, and the consequent specialisation of the studies of each individual, have rendered the need for such reports more than ever pressing; and if the course of true Science should still run smooth it is probable that the need will increase rather than diminish.

If time and space had permitted, I should have further particularised the Committees, occasionally appointed, on subjects connected with education. But I must leave this theme for some future President, and content myself with pointing out that the British Association alone among scientific societies concerns itself directly with these questions, and is open to appeals for counsel and support from the great teaching body of the country.

One of the principal methods by which this Association materially promotes the advancement of Science, and consequently one of its most important functions, consists in grants of money from its own income in aid of special scientific researches. The total amount so laid out during the forty-seven years of our existence has been no less than 44,000*l.*; and the average during the last ten years has been 1,450*l.* per annum. These

sums have not only been in the main wisely voted and usefully expended; but they have been themselves productive of much additional voluntary expenditure of both time and money on the part of those to whom the grants have been entrusted. The results have come back to the Association in the form of papers and reports, many of which have been printed in our volumes. By this appropriation of a large portion of its funds, the Association has to some extent anticipated, nay even it may have partly inspired the ideas, now so much discussed, of the Endowment of Research. And whether the aspirations of those who advocate such endowment be ever fully realised or not, there can I think be no doubt whatever that the Association in the matter of these grants has afforded a most powerful stimulus to original research and discovery.

Regarded from another point of view these grants, together with others to be hereafter mentioned, present a strong similarity to that useful institution, the Professoriate Extraordinary of Germany, to which there are no foundations exactly corresponding in this country. For, beside their more direct educational purpose, these Professorships are intended, like our own grants, to afford to special individuals an opportunity of following out the special work for which they have previously proved themselves competent. And in this respect the British Association may be regarded as supplying, to the extent of its means, an elasticity which is wanting in our own Universities.

Besides the funds which through your support are at the disposal of the British Association there are, as is well known to many here present, other funds of more or less similar character, at the disposal or subject to the recommendations of the Royal Society. There is the Donation Fund, the property of the Society; the Government Grant of 1,000*l.* per annum, administered by the Society; and the Government Fund of 4,000*l.* per annum (an experiment for five years) to be distributed by the Science and Art Department, both for research itself, and for the support of those engaged thereon, according to the recommendations of a Committee consisting mainly of Fellows of the Royal Society. To these might be added other funds in the hands of different Scientific Societies.

But although it must be admitted that the purposes of these various funds are not to be distinguished by any very simple line of demarcation, and that they may therefore occasionally appear to overlap one another, it may still, I think, be fairly maintained that this fact does not furnish any sufficient reason against their co-existence. There are many topics of research too minute in their range, too tentative in their present condition, to come fairly within the scope of the funds administered by the Royal Society. There are others, ample enough in their extent, and long enough in their necessary duration, to claim for their support a national grant, but which need to be actually set on foot or tried before they can fairly expect the recognition either of the public or of the Government. To these categories others might be added; but the above-mentioned

instances will perhaps suffice to show that even if larger and more permanent funds were devoted to the promotion of research than is the case at present, there would still be a field of activity open to the British Association as well as to other scientific bodies which may have funds at their disposal.

On the general question it is not difficult to offer strong arguments in favour of permanent national Scientific Institutions; nor is it difficult to picture to the mind an ideal future when Science and Art shall walk hand in hand together, led by a willing minister into the green pastures of the Endowment of Research. But while allowing this to be no impossible a future, we must still admit that there are other and less promising possibilities, which under existing circumstances cannot be altogether left out of our calculations. I am therefore on the whole inclined to think that, while not losing sight of larger schemes, the wisest policy, for the present at all events, and pending the experiment of the Government fund, will be to confine our efforts to a careful selection of definite persons to carry out definite pieces of work; leaving to them the honour (or the onus if they so think it) of justifying from time to time a continuation of the confidence which the Government or other supporting body may have once placed in them.

Passing from the proceedings to other features and functions of our body, it should be remembered that the continued existence of the Association must depend largely upon the support which it receives from its members and associates. Stinted in the funds so arising, its scientific effectiveness would be materially impaired; and deprived of them, its existence would be precarious. The amount at our disposal in each year will naturally vary with the population, with the accessibility, and with other circumstances of the place of meeting; there will be financially, as well as scientifically, good years and bad years. But we have in our invested capital a sum sufficient to tide over all probable fluctuations, and even to carry us efficiently through several years of financial famine, if ever such should occur. This seems to me sufficient; and we have therefore, I think, no need to increase our reserve, beyond perhaps the moderate addition which a prudent treasurer will always try to secure, against expenditure which often increases and rarely diminishes.

But however important this material support may be to our existence and well being, it is by no means all that is required. There is another factor which enters into the product, namely, the personal scientific support of our best men. It is, I think, not too much to say, that without their presence our meetings would fail in their chief and most important element, and had best be discontinued altogether. We make, it must be admitted, a demand of sensible magnitude in calling upon men who have been actively engaged during a great portion of the year, at a season when they may fairly look for relaxation, to attend a busy meeting, and to contribute to its proceedings; but unless a fair quota at least of our veterans, and a good muster of our younger men, put in their appearance,

our gatherings will be to little purpose. There was a period within my own recollection when it was uncertain whether the then younger members of our scientific growth would cast in their lot with us or not, and when the fate of the Association depended very much upon their decision. They decided in our favour; they have since become Presidents, Lecturers, and other functionaries of our body; with what result it is for you to judge.

Of the advantages which may possibly accrue to the locality in which our meetings are held, it is not for us to speak; but it is always a ground for sincere satisfaction to learn that our presence has been of any use in stimulating an interest, or in promoting local efforts, in the direction of Science.

The functions of the British Association do not, however, terminate with the meeting itself. Beside the special committees already mentioned, there remains a very important body, elected by the General Committee, viz., the Council, which assembles at the office in London from time to time as occasion requires. To this body belongs the duty of proposing a President, of preparing for the approval of the General Committee the list of Vice-Presidents and sectional officers, the selection of evening lecturers, and other arrangements for the coming meeting.

At the present time another class of questions occupies a good deal of the attention of the Council. In the first generation of the Association, and during the period of unwritten, but not yet traditional, law, questions relating to our own organisation or procedure either "settled themselves," or were wisely left to the discretionary powers of those who had taken part in our proceedings during the early years of our existence. These and other kindred subjects now require more careful formularisation and more deliberate sanction. And it is on the shoulders of the Council that the weight of these matters in general falls. These facts deserve especial mention on the present occasion, because one part of our business at the close of this meeting will be to bid farewell officially to one who has served us as Assistant Secretary so long and so assiduously that he has latterly become our main repertory of information, and our mentor upon questions of precedent and procedure. The post hitherto held by Mr. Griffith (for it is to him that I allude) will doubtless be well filled by the able and energetic member who has been nominated in his place; but I doubt not that even he will be glad for some time to come to draw largely upon the knowledge and experience of his predecessor.

But, beside matters of internal arrangement and organisation, the duties of the Council comprise a variety of scientific subjects referred to them by the General Committee, at the instance of the Committee of Recommendations, for deliberation and occasionally for action. With the increasing activity of our body in general, and more particularly with that of our various officers, these duties have of late years become more varied and onerous than formerly; nor is it to be wished that they should diminish in either variety or extent.

Once more, questions beyond our own constitution, and even beyond the scope of our own immediate action, such as education, legislation affecting either the promotion or the applications of science to industrial and social life, which have suggested themselves at our meetings, and received the preliminary sanction of our Committee of Recommendations, are frequently referred to our Council. These, and others which it is unnecessary to particularise, whether discussed in full Council or in committees specially appointed by that body, render the duties of our councillors as onerous as they are important.

While the Government has at all times, but in a more marked manner of late years, recognised the Royal Society of London, with representatives from the sister societies of Dublin and of Edinburgh, as the body to which it should look for counsel and advice upon scientific questions, it has still never shown itself indisposed to receive and entertain any well-considered recommendation from the British Association. Two special causes have in all probability contributed largely to this result. First, the variety of elements comprised by the Association, on account of which its recommendations imply a more general concurrence of scientific opinion than those of any other scientific body. Secondly, the peculiar fact, that our period of maximum activity coincides with that of minimum activity of other scientific bodies, is often of the highest importance. At the very time when the other bodies are least able, we are most able, to give deliberate consideration, and formal sanction, to recommendations whether in the form of applications to Government or otherwise which may arise. In many of these, time is an element so essential, that it is not too much to say, that without the intervention of the British Association many opportunities for the advancement of Science, especially at the seasons in question, might have been lost. The Government has moreover formally recognised our scientific existence by appointing our President for the time being a member of the Government Fund Committee; and the public has added its testimony to our importance and utility by imposing upon our President and officers a variety of duties, among which are conspicuous those which arise out of its very liberal exercise of civic and other hospitality.

Of the nature and functions of the Presidential address this is perhaps neither the time nor the place to speak; but if I might for a moment forget the purpose for which we are now assembled, I would take the opportunity of reminding those who have not attended many of our former meetings that our annual volumes contain a long series of addresses on the progress of Science, from a number of our most eminent men, to which there is perhaps no parallel elsewhere. These addresses are perhaps as remarkable for their variety in mode of treatment as for the value of their subject-matter. Some of our Presidents, and especially those who officiated in the earlier days of our existence, have passed in review the various branches of Science, and have noted the progress made in

each during the current year. But, as the various Sciences have demanded more and more special treatment on the part of those who seriously pursue them, so have the cases of individuals who can of their own knowledge give anything approaching to a general review become more and more rare. To this may be added the fact that although no year is so barren as to fail in affording sufficient crop for a strictly scientific budget, or for a detailed report of progress in research, yet one year is more fertile than another in growths of sufficient prominence to arrest the attention of the general public, and to supply topics suitable for the address. On these accounts apparently such a Presidential survey has ceased to be annual, and has dropped into an intermittence of longer period. Some Presidents have made a scientific principle, such as the Time-element in natural phenomena, or Continuity, or Natural Selection, the theme of their discourse, and have gathered illustrations from various branches of knowledge. Others again, taking their own special subject as a fundamental note, and thence modulating into other kindred keys, have borne testimony to the fact that no subject is so special as to be devoid of bearing or of influence on many others. Some have described the successive stages of even a single but important investigation; and while tracing the growth of that particular item, and of the ideas involved in it, have incidentally shown to the outer world what manner of business a serious investigation is. But there is happily no pattern or precedent which the President is bound to follow; both in range of subject-matter and in mode of treatment each has exercised his undoubted right of taking an independent line. And it can hardly be doubted that a judicious exercise of this freedom has contributed more than anything else to sustain the interest of a series of annual discourses extending now over nearly half a century.

The nature of the subjects which may fairly come within the scope of such a discourse has of late been much discussed; and the question is one upon which everyone of course is entitled to form his own judgment; but lest there should be any misapprehension as to how far it concerns us in our corporate capacity, it will be well to remind my hearers that as, on the one hand, there is no discussion on the Presidential address, and the members as a body express no formal opinion upon it, so, on the other, the Association cannot fairly be considered as in any way committed to its tenour or conclusions. Whether this immunity from comment and reply be really on the whole so advantageous to the President as might be supposed need not here be discussed; but suffice it to say, that the case of an audience assembled to listen without discussion finds a parallel elsewhere, and in the parallel case it is not generally considered that the result is altogether either advantageous to the speaker or conducive to excellence in the discourse.

But, apart from this, the question of a limitation of range in the subject-matter for the Presidential address is not quite so simple as may at first sight appear. It must, in fact, be borne in mind that, while on

the one hand knowledge is distinct from opinion, from feeling, and from all other modes of subjective impression, still the limits of knowledge are at all times expanding, and the boundaries of the known and the unknown are never rigid or permanently fixed. That which in time past or present has belonged to one category may in time future belong to the other. Our ignorance consists partly in ignorance of actual facts, and partly also in ignorance of the possible range of ascertainable fact. If we could lay down beforehand precise limits of possible knowledge, the problem of Physical Science would be already half solved. But the question to which the scientific explorer has often to address himself is not merely whether he is able to solve this or that problem, but whether he can so far unravel the tangled threads of the matter with which he has to deal as to weave them into a definite problem at all. He is not like a candidate at an examination with a precise set of questions placed before him; he must first himself act the part of the examiner and select questions from the repertory of nature, and upon them found others, which in some sense are capable of definite solution. If his eye seem dim, he must look steadfastly and with hope into the misty vision, until the very clouds wreath themselves into definite forms. If his ear seem dull, he must listen patiently and with sympathetic trust to the intricate whisperings of nature,—the goddess, as she has been called, of a hundred voices—until here and there he can pick out a few simple notes to which his own powers can resound. If, then, at a moment when he finds himself placed on a pinnacle from which he is called upon to take a perspective survey of the range of science, and to tell us what he can see from his vantage ground; if, at such a moment, after straining his gaze to the very verge of the horizon, and after describing the most distant of well-defined objects, he should give utterance also to some of the subjective impressions which he is conscious of receiving from regions beyond; if he should depict possibilities which seem opening to his view; if he should explain why he thinks this a mere blind alley and that an open path; then the fault and the loss would be alike ours if we refused to listen calmly, and temperately to form our own judgment on what we hear; then assuredly it is we who would be committing the error of confounding matters of fact and matters of opinion if we failed to discriminate between the various elements contained in such a discourse, and assumed that they had all been put on the same footing.

But to whatever decision we may each come on these controverted points, one thing appears clear from a retrospect of past experience, viz., that first or last, either at the outset in his choice of subject or in the conclusions ultimately drawn therefrom, the President, according to his own account at least, finds himself on every occasion in a position of "exceptional or more than usual difficulty." And your present representative, like his predecessors, feels himself this moment in a similar predicament. The reason which he now offers is that the branch of

science which he represents is one whose lines of advance, viewed from a mathematician's own point of view, offer so few points of contact with the ordinary experiences of life or modes of thought, that any account of its actual progress which he might have attempted must have failed in the first requisite of an address, namely, that of being intelligible.

Now if this esoteric view had been the only aspect of the subject which he could present to his hearers, he might well have given up the attempt in despair. But although in its technical character Mathematical Science suffers the inconveniences, while it enjoys the dignity, of its Olympian position, still in a less formal garb, or in disguise, if you are pleased so to call it, it is found present at many an unexpected turn; and although some of us may never have learnt its special language, not a few have, all through our scientific life, and even in almost every accurate utterance, like Molière's well known character, been talking mathematics without knowing it. It is, moreover, a fact not to be overlooked that the appearance of isolation, so conspicuous in mathematics, appertains in a greater or less degree to all other sciences, and perhaps also to all pursuits in life. In its highest flight each soars to a distance from its fellows. Each is pursued alone for its own sake, and without reference to its connection with, or its application to, any other subject. The pioneer and the advanced guard are of necessity separated from the main body, and in this respect mathematics does not materially differ from its neighbours. And, therefore, as the solitariness of mathematics has been a frequent theme of discourse, it may be not altogether unprofitable to dwell for a short time upon the other side of the question, and to inquire whether there be not points of contact in method or in subject-matter between mathematics and the outer world which have been frequently overlooked; whether its lines do not in some cases run parallel to those of other occupations and purposes of life; and lastly, whether we may not hope for some change in the attitude too often assumed towards it by the representatives of other branches of knowledge and of mental activity.

In his Preface to the 'Principia' Newton gives expression to some general ideas which may well serve as the key-note for all future utterances on the relation of mathematics to natural, including also therein what are commonly called artificial, phenomena.

"The ancients divided mechanics into two parts, rational and practical; and since artizans often work inaccurately, it came to pass that mechanics and geometry were distinguished in this way, that everything accurate was referred to geometry, and everything inaccurate to mechanics. But the inaccuracies appertain to the artizan and not to the art, and geometry itself has its foundation in mechanical practice, and is in fact nothing else than that part of universal mechanics which accurately lays down and demonstrates the art of measuring." He next explains that rational mechanics is the science of motion resulting from

forces, and adds, "The whole difficulty of philosophy seems to me to lie in investigating the forces of nature from the phenomena of motion, and in demonstrating that from these forces other phenomena will ensue." Then, after stating the problems of which he has treated in the work itself, he says, "I would that all other natural phenomena might similarly be deduced from mechanical principles. For many things move me to suspect that everything depends upon certain forces in virtue of which the particles of bodies, through forces not yet understood, are either impelled together so as to cohere in regular figures, or are repelled and recede from one another."

Newton's views, then, are clear. He regards mathematics, not as a method independent of, though applicable to, various subjects, but as itself the higher side or aspect of the subjects themselves; and it would be little more than a translation of his notions into other language, little more than a paraphrase of his own words, if we were to describe the mathematical as one aspect of the material world itself, apart from which all other aspects are but incomplete sketches, and, however accurate after their own kind, are still liable to the imperfections of the inaccurate artificer. Mr. Burrowes, in his Preface to the first volume of the 'Transactions of the Royal Irish Academy,' has carried out the same argument, approaching it from the other side. "No one science," he says, "is so little connected with the rest as not to afford many principles whose use may extend considerably beyond the science to which they primarily belong, and no proposition is so purely theoretical as to be incapable of being applied to practical purposes. There is no apparent connexion between duration and the cycloidal arch, the properties of which have furnished us with the best method of measuring time; and he who has made himself master of the nature and affections of the logarithmic curve has advanced considerably towards ascertaining the proportionable density of the air at various distances from the earth. The researches of the mathematician are the only sure ground on which we can reason from experiments; and how far experimental science may assist commercial interests is evinced by the success of manufactures in countries where the hand of the artificer has taken its direction from the philosopher. Every manufacture is in reality but a chemical process, and the machinery requisite for carrying it on but the right application of certain propositions in rational mechanics." So far your Academician. Every subject, therefore, whether in its usual acceptation scientific or otherwise, may have a mathematical aspect; as soon, in fact, as it becomes a matter of strict measurement, or of numerical statement, so soon does it enter upon a mathematical phase. This phase may, or it may not, be a prelude to another in which the laws of the subject are expressed in algebraical formulæ or represented by geometrical figures. But the real gist of the business does not always lie in the mode of expression, and the fascination of the formulæ or other mathematical

paraphernalia may after all be little more than that of a theatrical transformation scene. The process of reducing to formulæ is really one of abstraction, the results of which are not always wholly on the side of gain; in fact, through the process itself the subject may lose in one respect even more than it gains in another. But long before such abstraction is completely attained, and even in cases where it is never attained at all, a subject may to all intents and purposes become mathematical. It is not so much elaborate calculations or abstruse processes which characterise this phase as the principles of precision, of exactness, and of proportion. But these are principles with which no true knowledge can entirely dispense. If it be the general scientific spirit which at the outset moves upon the face of the waters, and out of the unknown depth brings forth light and living forms, it is no less the mathematical spirit which breathes the breath of life into what would otherwise have ever remained mere dry bones of fact, which reunites the scattered limbs and re-creates from them a new and organic whole.

And as a matter of fact, in the words used by Professor Jellett at our meeting at Belfast, viz., "Not only are we applying our methods to many sciences already recognised as belonging to the legitimate province of mathematics, but we are learning to apply the same instrument to sciences hitherto wholly or partially independent of its authority. Physical Science is learning more and more every day to see in the phenomena of Nature modifications of that one phenomenon (namely, Motion) which is peculiarly under the power of mathematics." Echoes are these, far off and faint perhaps, but still true echoes, in answer to Newton's wish that all these phenomena may some day "be deduced from mechanical principles."

If, turning from this aspect of the subject, it were my purpose to enumerate how the same tendency has evinced itself in the Arts, unconsciously it may be to the artists themselves, I might call as witnesses each one in turn with full reliance on the testimony which they would bear And, having more special reference to mathematics, I might confidently point to the accuracy of measurement, to the truth of curve, which according to modern investigation is the key to the perfection of classic art. I might triumphantly cite not only the architects of all ages, whose art so manifestly rests upon mathematical principles; but I might cite also the literary as well as the artistic remains of the great artists of Cinquecento, both painters and sculptors, in evidence of the geometry and the mechanics which, having been laid at the foundation, appear to have found their way upwards through the superstructure of their works. And in a less ambitious sphere, but nearer to ourselves in both time and place, I might point with satisfaction to the great school of English constructors of the 18th century in the domestic arts; and remind you that not only the engineer and the architect, but even the cabinetmakers, devoted half the space of their books to perspective and to the principles

whereby solid figures may be delineated on paper, or what is now termed descriptive geometry.

Nor perhaps would the sciences which concern themselves with reasoning and speech, nor the kindred art of Music, nor even Literature itself, if thoroughly probed, offer fewer points of dependence upon the science of which I am speaking. What, in fact, is Logic but that part of universal reasoning; Grammar but that part of universal speech; Harmony and Counterpoint but that part of universal music, "which accurately lays down," and demonstrates (so far as demonstration is possible) precise methods appertaining to each of these Arts? And I might even appeal to the common consent which speaks of the mathematical as the pattern form of reasoning and model of a precise style.

Taking, then, precision and exactness as the characteristics which distinguish the mathematical phase of a subject, we are naturally led to expect that the approach to such a phase will be indicated by increasing application of the principle of measurement, and by the importance which is attached to numerical results. And this very necessary condition for progress may, I think, be fairly described as one of the main features of scientific advance in the present day.

If it were my purpose, by descending into the arena of special sciences, to show how the most various investigations alike tend to issue in measurement, and to that extent to assume a mathematical phase, I should be embarrassed by the abundance of instances which might be adduced. I will therefore confine myself to a passing notice of a very few, selecting those which exemplify not only the general tendency, but also the special character of the measurements now particularly required, viz., that of minuteness, and the indirect method by which alone we can at present hope to approach them. An object having a diameter of an 80,000th of an inch is perhaps the smallest of which the microscope could give any well-defined representation; and it is improbable that one of 120,000th of an inch could be singly discerned with the highest powers at our command. But the solar beams and the electric light reveal to us the presence of bodies far smaller than these. And, in the absence of any means of observing them singly, Professor Tyndall has suggested a scale of these minute objects in terms of the lengths of luminiferous waves. To this he was led, not by any attempt at individual measurement, but by taking account of them in the aggregate, and observing the tints which they scatter laterally when clustered in the form of actinic clouds. The small bodies with which experimental Science has recently come into contact are not confined to gaseous molecules, but comprise also complete organisms; and the same philosopher has made a profound study of the momentous influence exerted by these minute organisms in the economy of life. And if, in view of their specific effects, whether deleterious or other, on human life, any qualitative classification, or quantitative estimate be ever possible, it seems that it must be effected by some such method as that indicated above.

Again, to enumerate a few more instances of the measurement of minute quantities, there are the average distances of molecules from one another in various gases and at various pressures; the length of their free path, or range open for their motion without coming into collision; there are movements causing the pressures and differences of pressure under which Mr. Crookes' radiometers execute their wonderful revolutions. There are the excursions of the air while transmitting notes of high pitch, which through the researches of Lord Rayleigh appear to be of a diminutiveness altogether unexpected. There are the molecular actions brought into play in the remarkable experiments by Dr. Kerr, who has succeeded, where even Faraday failed, in effecting a visible rotation of the plane of polarisation of light in its passage through electrified dielectrics, and on its reflexion at the surface of a magnet. To take one more instance, which must be present to the minds of us all, there are the infinitesimal ripples of the vibrating plate in Mr. Graham Bell's most marvellous invention. Of the nodes and ventral segments in the plate of the telephone which actually converts sound into electricity and electricity into sound, we can at present form no conception. All that can now be said is that the most perfect specimens of Chladni's sand figures on a vibrating plate, or of Kundt's lycopodium heaps in a musical tube, or even Mr. Sedley Taylor's more delicate vortices in the films of the Phoneidoscope, are rough and sketchy compared with these. For notwithstanding the fact that in the movements of the Telephone-plate we have actually in our hand the solution of that old world problem, the construction of a speaking machine; yet the characters in which that solution is expressed are too small for our powers of decipherment. In movements such as these we seem to lose sight of the distinction, or perhaps we have unconsciously passed the boundary between massive and molecular motion.

Through the Phonograph we have not only a transformation but a permanent and tangible record of the mechanism of speech. But the differences upon which articulation (apart from loudness, pitch, and quality) depends, appear from the experiments of Fleeming Jenkin and of others to be of microscopic size. The Microphone affords another instance of the unexpected value of minute variations,—in this case of electric currents; and it is remarkable that the gist of the instrument seems to lie in obtaining and perfecting that which electricians have hitherto most scrupulously avoided, viz., loose contact

Once more, Mr. De La Rue has brought forward as one of the results derived from his stupendous battery of 10,000 cells, strong evidence for supposing that a voltaic discharge, even when apparently continuous, may still be an intermittent phenomenon; but all that is known of the period of such intermittence is, that it must recur at exceedingly short intervals. And in connexion with this subject, it may be added that, whatever be the ultimate explanation of the strange stratification which the voltaic discharge undergoes in rarefied gases, it is clear that the alternate disposi-

tion of light and darkness must be dependent on some periodic distribution in space or sequence in time which can at present be dealt with only in a very general way. In the exhausted column we have a vehicle for electricity not constant like an ordinary conductor, but itself modified by the passage of the discharge, and perhaps subject to laws differing materially from those which it obeys at atmospheric pressure. It may also be that some of the features accompanying stratification form a magnified image of phenomena belonging to disruptive discharges in general; and that consequently, so far from expecting among the known facts of the latter any clue to an explanation of the former, we must hope ultimately to find in the former an elucidation of what is at present obscure in the latter. A prudent philosopher usually avoids hazarding any forecast of the practical application of a purely scientific research. But it would seem that the configuration of these striæ might some day prove a very delicate means of estimating low pressures, and perhaps also for effecting some electrical measurements.

Now, it is a curious fact that almost the only small quantities of which we have as yet any actual measurements are the wave lengths of light; and that all others, excepting so far as they can be deduced from these, await future determination. In the meantime, when unable to approach these small quantities individually, the method to which we are obliged to have recourse is, as indicated above, that of averages, whereby, disregarding the circumstances of each particular case, we calculate the average size, the average velocity, the average direction, &c., of a large number of instances. But although this method is based upon experience, and leads to results which may be accepted as substantially true; although it may be applicable to any finite interval of time, or over any finite area of space (that is, for all practical purposes of life), there is no evidence to show that it is so when the dimensions of interval or of area are indefinitely diminished. The truth is that the simplicity of nature which we at present grasp is really the result of infinite complexity; and that below the uniformity there underlies a diversity whose depths we have not yet probed, and whose secret places are still beyond our reach.

The present is not an occasion for multiplying illustrations, but I can hardly omit a passing allusion to one all-important instance of the application of the statistical method. Without its aid social life, or the History of Life and Death, could not be conceived at all, or only in the most superficial manner. Without it we could never attain to any clear ideas of the condition of the Poor, we could never hope for any solid amelioration of their condition or prospects. Without its aid, sanitary measures, and even medicine, would be powerless. Without it, the politician and the philanthropist would alike be wandering over a trackless desert.

It is, however, not so much from the side of Science at large as from that of Mathematics itself, that I desire to speak. I wish from the latter point of view to indicate connexions between Mathematics and other sub-

jects, to prove that hers is not after all such a far-off region, nor so undecipherable an alphabet, and to show that even at unlikely spots we may trace under-currents of thought which having issued from a common source fertilise alike the mathematical and the non-mathematical world.

Having this in view, I propose to make the subject of special remark some processes peculiar to modern Mathematics; and, partly with the object of incidentally removing some current misapprehensions, I have selected for examination three methods in respect of which mathematicians are often thought to have exceeded all reasonable limits of speculation. and to have adopted for unknown purposes an unknown tongue. And it will be my endeavour to show not only that in these very cases our science has not outstepped its own legitimate range, but that even art and literature have unconsciously employed methods similar in principle. The three methods in question are, first, that of Imaginary Quantities; secondly, that of Manifold Space; and thirdly, that of Geometry not according to Euclid.

First it is objected that, abandoning the more cautious methods of ancient mathematicians, we have admitted into our formulæ quantities which by our own showing, and even in our own nomenclature, are imaginary or impossible; nay, more, that out of them we have formed a variety of new algebras to which there is no counterpart whatever in reality; but from which we claim to arrive at possible and certain results.

On this head it is in Dublin, if anywhere, that I may be permitted to speak. For to the fertile imagination of the late Astronomer Royal for Ireland we are indebted for that marvellous Calculus of Quaternions, which is only now beginning to be fully understood, and which has not yet received all the applications of which it is doubtless capable. And even although this calculus be not coextensive with another which almost simultaneously germinated on the Continent, nor with ideas more recently developed in America; yet it must always hold its position as an original discovery, and as a representative of one of the two great groups of generalised algebras (viz., those the squares of whose units are respectively negative unity and zero), the common origin of which must still be marked on our intellectual map as an unknown region. Well do I recollect how in its early days we used to handle the method as a magician's page might try to wield his master's wand, trembling as it were between hope and fear, and hardly knowing whether to trust our own results until they had been submitted to the present and ever-ready counsel of Sir W. R. Hamilton himself.

To fix our ideas, consider the measurement of a line, or the reckoning of time, or the performance of any mathematical operation. A line may be measured in one direction or in the opposite; time may be reckoned forward or backward; an operation may be performed or be reversed, it may be done or may be undone; and if having once reversed any of these processes we reverse it a second time, we shall find that we have come

back to the original direction of measurement or of reckoning, or to the original kind of operation.

Suppose, however, that at some stage of a calculation our formulæ indicate an alteration in the mode of measurement such that, if the alteration be repeated, a condition of things, not the same as, but the reverse of the original, will be produced. Or suppose that, at a certain stage, our transformations indicate that time is to be reckoned in some manner different from future or past, but still in a way having definite algebraical connexion with time which is gone and time which is to come. It is clear that in actual experience there is no process to which such measurements correspond. Time has no meaning except as future or past; and the present is but the meeting point of the two. Or, once more, suppose that we are gravely told that all circles pass through the same two imaginary points at an infinite distance, and that every line drawn through one of these points is perpendicular to itself. On hearing the statement, we shall probably whisper, with a smile or a sigh, that we hope it is not true; but that in any case it is a long way off, and perhaps, after all, it does not very much signify. If, however, as mathematicians we are not satisfied to dismiss the question on these terms, we ourselves must admit that we have here reached a definite point of issue. Our science must either give a rational account of the dilemma, or yield the position as no longer tenable.

Special modes of explaining this anomalous state of things have occurred to mathematicians. But, omitting details as unsuited to the present occasion, it will, I think, be sufficient to point out in general terms that a solution of the difficulty is to be found in the fact that the formulæ which give rise to these results are more comprehensive than the signification assigned to them; and when we pass out of the condition of things first contemplated they cannot (as it is obvious they ought not) give us any results intelligible on that basis. But it does not therefore by any means follow that upon a more enlarged basis the formulæ are incapable of interpretation; on the contrary, the difficulty at which we have arrived indicates that there must be some more comprehensive statement of the problem which will include cases impossible in the more limited, but possible in the wider view of the subject.

A very simple instance will illustrate the matter. If from a point outside a circle we draw a straight line to touch the curve, the distance between the starting point and the point of contact has certain geometrical properties. If the starting point be shifted nearer and nearer to the circle the distance in question becomes shorter, and ultimately vanishes. But as soon as the point passes to the interior of the circle the notion of a tangent and distance to the point of contact cease to have any meaning; and the same anomalous condition of things prevails as long as the point remains in the interior. But if the point be shifted still further until it emerges on the other side, the tangent and its properties resume their

reality, and are as intelligible as before. Now the process whereby we have passed from the possible to the impossible, and again repassed to the possible (namely, the shifting of the starting point) is a perfectly continuous one, while the conditions of the problem as stated above have abruptly changed. If, however, we replace the idea of a line touching by that of a line cutting the circle, and the distance of the point of contact by the distances at which the line is intercepted by the curve, it will easily be seen that the latter includes the former as a limiting case, when the cutting line is turned about the starting point until it coincides with the tangent itself. And further, that the two intercepts have a perfectly distinct and intelligible meaning whether the point be outside or inside the area. The only difference is that in the first case the intercepts are measured in the same direction; in the latter in opposite directions.

The foregoing instance has shown one purpose which these imaginaries may serve, viz., as marks indicating a limit to a particular condition of things, to the application of a particular law, or pointing out a stage where a more comprehensive law is required. To attain to such a law we must, as in the instance of the circle and tangent, reconsider our statement of the problem; we must go back to the principle from which we set out, and ascertain whether it may not be modified or enlarged. And even if in any particular investigation, wherein imaginaries have occurred, the most comprehensive statement of the problem of which we are at present capable fails to give an actual representation of these quantities; if they must for the present be relegated to the category of imaginaries; it still does not follow that we may not at some future time find a law which will endow them with reality, nor that in the meantime we need hesitate to employ them, in accordance with the great principle of continuity, for bringing out correct results.

If, moreover, both in Geometry and in Algebra we occasionally make use of points or of quantities, which from our present outlook have no real existence, which can neither be delineated in space of which we have experience, nor measured by scale as we count measurement; if these imaginaries, as they are termed, are called up by legitimate processes of our science; if they serve the purpose not merely of suggesting ideas, but of actually conducting us to practical conclusions; if all this be true in abstract science, I may perhaps be allowed to point out, in illustration of my argument, that in Art unreal forms are frequently used for suggesting ideas, for conveying a meaning for which no others seem to be suitable or adequate. Are not forms unknown to Biology, situations incompatible with gravitation, positions which challenge not merely the stability but even the possibility of equilibrium,—are not these the very means to which the artist often has recourse in order to convey his meaning and to fulfil his mission? Who that has ever revelled in the ornamentation of the Renaissance, in the extraordinary transitions from the animal to the vegetable, from faunic to floral forms, and from these again to almost

purely geometric curves, who has not felt that these imaginaries have a claim to recognition very similar to that of their congeners in mathematics? How is it that the grotesque paintings of the Middle Ages, the fantastic sculpture of remote nations, and even the rude art of the prehistoric past, still impress us, and have an interest over and above their antiquarian value; unless it be that they are symbols which, although hard of interpretation when taken alone, are yet capable from a more comprehensive point of view of leading us mentally to something beyond themselves, and to truths which, although reached through them, have a reality scarcely to be attributed to their outward forms?

Again, if we turn from Art to Letters, truth to nature and to fact is undoubtedly a characteristic of sterling literature; and yet in the delineation of outward nature itself, still more in that of feelings and affections, of the secret parts of character and motives of conduct, it frequently happens that the writer is driven to imagery, to an analogy, or even to a paradox, in order to give utterance to that of which there is no direct counterpart in recognised speech. And yet which of us cannot find a meaning for these literary figures, an inward response to imaginative poetry, to social fiction, or even to those tales of giant and fairyland written, it is supposed, only for the nursery or schoolroom? But in order thus to reanimate these things with a meaning beyond that of the mere words, have we not to reconsider our first position, to enlarge the ideas with which we started; have we not to cast about for some thing which is common to the idea conveyed and to the subject actually described, and to seek for the sympathetic spring which underlies both; have we not, like the mathematician, to go back as it were to some first principles, or, as it is pleasanter to describe it, to become again as a little child?

Passing to the second of the three methods, viz., that of Manifold Space, it may first be remarked that our whole experience of space is in three dimensions, viz., of that which has length, breadth, and thickness; and if for certain purposes we restrict our ideas to two dimensions as in plane geometry, or to one dimension as in the division of a straight line, we do this only by consciously and of deliberate purpose setting aside, but not annihilating, the remaining one or two dimensions. Negation, as Hegel has justly remarked, implies that which is negatived, or, as he expresses it, affirms the opposite. It is by abstraction from previous experience, by a limitation of its results, and not by any independent process, that we arrive at the idea of space whose dimensions are less than three.

It is doubtless on this account that problems in plane geometry which, although capable of solution on their own account, become much more intelligible, more easy of extension, if viewed in connexion with solid space, and as special cases of corresponding problems in solid geometry. So eminently is this the case, that the very language of the more general method often leads us almost intuitively to conclusions which, from the more restricted point of view, require long and laborious proof. Such a

change in the base of operations has, in fact, been successfully made in geometry of two dimensions, and although we have not the same experimental data for the further steps, yet neither the modes of reasoning, nor the validity of its conclusions, are in any way affected by applying an analogous mental process to geometry of three dimensions; and by regarding figures in space of three dimensions as sections of figures in space of four, in the same way that figures in plane are sometimes considered as sections of figures in solid space. The addition of a fourth dimension to space not only extends the actual properties of geometrical figures, but it also adds new properties which are often useful for the purposes of transformation or of proof. Thus it has recently been shown that in four dimensions a closed material shell could be turned inside out by simple flexure, without either stretching or tearing; and that in such a space it is impossible to tie a knot.

Again, the solution of problems in geometry is often effected by means of algebra; and as three measurements, or co-ordinates as they are called, determine the position of a point in space, so do three letters or measureable quantities serve for the same purpose in the language of algebra. Now, many algebraical problems involving three unknown or variable quantities admit of being generalised so as to give problems involving many such quantities. And as, on the one hand, to every algebraical problem involving unknown quantities or variables by ones, or by twos, or by threes, there corresponds a problem in geometry of one or of two or of three dimensions; so on the other it may be said that to every algebraical problem involving many variables there corresponds a problem in geometry of many dimensions.

There is, however, another aspect under which even ordinary space presents to us a four-fold, or indeed a mani-fold, character. In modern Physics, space is regarded not as a vacuum in which bodies are placed and forces have play, but rather as a plenum with which matter is coextensive. And from a physical point of view the properties of space are the properties of matter, or of the medium which fills it. Similarly from a mathematical point of view, space may be regarded as a *locus in quo*, as a plenum, filled with those elements of geometrical magnitude which we take as fundamental. These elements need not always be the same. For different purposes different elements may be chosen; and upon the degree of complexity of the subject of our choice will depend the internal structure or mani-foldness of space.

Thus, beginning with the simplest case, a point may have any singly infinite multitude of positions in a line, which gives a one-fold system of points in a line. The line may revolve in a plane about any one of its points, giving a two-fold system of points in a plane; and the plane may revolve about any one of the lines, giving a three-fold system of points in space.

Suppose, however, that we take a straight line as our element, and

conceive space as filled with such lines. This will be the case if we take two planes, *e.g.*, two parallel planes, and join every point in one with every point in the other. Now the points in a plane form a two-fold system, and it therefore follows that the system of lines is four-fold; in other words, space regarded as a plenum of lines is four-fold. The same result follows from the consideration that the lines in a plane, and the planes through a point, are each two-fold.

Again, if we take a sphere as our element we can through any point as a centre draw a singly infinite number of spheres, but the number of such centres is triply infinite; hence space as a plenum of spheres is four-fold. And, generally, space as a plenum of surfaces has a mani-foldness equal to the number of constants required to determine the surface. Although it would be beyond our present purpose to attempt to pursue the subject further, it should not pass unnoticed that the identity in the four-fold character of space, as derived on the one hand from a system of straight lines, and on the other from a system of spheres, is intimately connected with the principles established by Sophus Lie in his researches on the correlation of these figures.

If we take a circle as our element we can around any point in a plane as a centre draw a singly infinite system of circles; but the number of such centres in a plane is doubly infinite; hence the circles in a plane form a three-fold system, and as the planes in space form a three-fold system, it follows that space as a plenum of circles is six-fold.

Again, if we take a circle as our element, we may regard it as a section either of a sphere, or of a right cone (given except in position) by a plane perpendicular to the axis. In the former case the position of the centre is three-fold; the directions of the plane, like that of a pencil of lines perpendicular thereto, two-fold; and the radius of the sphere one-fold; six-fold in all. In the latter case, the position of the vertex is three-fold; the direction of the axis two-fold; and the distance of the plane of section one-fold; six-fold in all, as before. Hence space as a plenum of circles is six-fold.

Similarly, if we take a conic as our element we may regard it as a section of a right cone (given except in position) by a plane. If the nature of the conic be defined, the plane of section will be inclined at a fixed angle to the axis; otherwise it will be free to take any inclination whatever. This being so, the position of the vertex will be three-fold; the direction of the axis two-fold; the distance of the plane of section from the vertex one-fold; and the direction of that plane one-fold if the conic be defined, two-fold if it be not defined. Hence, space as a plenum of definite conics will be seven-fold, as a plenum of conics in general eight-fold. And so on for curves of higher degrees.

This is in fact the whole story and mystery of manifold space. It is not seriously regarded as a reality in the same sense as ordinary space;

it is a mode of representation, or a method which, having served its purpose, vanishes from the scene. Like a rainbow, if we try to grasp it, it eludes our very touch; but, like a rainbow, it arises out of real conditions of known and tangible quantities, and if rightly apprehended it is a true and valuable expression of natural laws, and serves a definite purpose in the science of which it forms part.

Again, if we seek a counterpart of this in common life, I might remind you that perspective in drawing is itself a method not altogether dissimilar to that of which I have been speaking; and that the third dimension of space, as represented in a picture, has its origin in the painter's mind, and is due to his skill, but has no real existence upon the canvas which is the groundwork of his art. Or again, turning to literature, when in legendary tales, or in works of fiction, things past and future are pictured as present, has not the poetic fancy correlated time with the three dimensions of space, and brought all alike to a common focus? Or once more, when space already filled with material substances is mentally peopled with immaterial beings, may not the imagination be regarded as having added a new element to the capacity of space, a fourth dimension of which there is no evidence in experimental fact?

The third method proposed for special remark is that which has been termed Non-Euclidean Geometry; and the train of reasoning which has led to it may be described in general terms as follows: some of the properties of space which on account of their simplicity, theoretical as well as practical, have, in constructing the ordinary system of geometry, been considered as fundamental, are now seen to be particular cases of more general properties. Thus a plane surface, and a straight line, may be regarded as special instances of surfaces and lines whose curvature is everywhere uniform or constant. And it is perhaps not difficult to see that, when the special notions of flatness and straightness are abandoned, many properties of geometrical figures which we are in the habit of regarding as fundamental will undergo profound modification. Thus a plane may be considered as a special case of the sphere, viz., the limit to which a sphere approaches when its radius is increased without limit. But even this consideration trenches upon an elementary proposition relating to one of the simplest of geometrical figures. In plane triangles the interior angles are together equal to two right angles; but in triangles traced on the surface of a sphere this proposition does not hold good. To this, other instances might be added.

Further, these modifications may affect not only our ideas of particular geometrical figures, but the very axioms of the Science itself. Thus, the idea, which in fact lies at the foundation of Euclid's method, viz., that a geometrical figure may be moved in space without change of size or alteration of form, entirely falls away, or becomes only approximate in a space wherein dimension and form are dependent upon position. For instance, if we consider merely the case of figures traced on a flattened globe like

the earth's surface, or upon an eggshell, such figures cannot be made to slide upon the surface without change of form, as is the case with figures traced upon a plane or even upon a sphere. But, further still, these generalisations are not restricted to the case of figures traced upon a surface; they may apply also to solid figures in a space whose very configuration varies from point to point. We may, for instance, imagine a space in which our rule or scale of measurement varies as it extends, or as it moves about, in one direction or another; a space, in fact, whose geometric density is not uniformly distributed. Thus we might picture to ourselves such a space as a field having a more or less complicated distribution of temperature, and our scale as a rod instantaneously susceptible of expansion or contraction under the influence of heat: or we might suppose space to be even crystalline in its geometric formation, and our scale and measuring instruments to accept the structure of the locality in which they are applied. These ideas are doubtless difficult of apprehension, at all events at the outset; but Helmholtz has pointed out a very familiar phenomenon which may be regarded as a diagram of such a kind of space. The picture formed by reflexion from a plane mirror may be taken as a correct representation of ordinary space, in which, subject to the usual laws of perspective, every object appears in the same form and of the same dimensions whatever be its position. In like manner the picture formed by reflexion from a curved mirror may be regarded as the representation of a space wherein dimension and form are dependent upon position. Thus in an ordinary convex mirror objects appear smaller as they recede laterally from the centre of the picture; straight lines become curved; objects infinitely distant in front of the mirror appear at a distance only equal to the focal length behind. And by suitable modifications in the curvature of the mirror, representations could similarly be obtained of space of various configurations.

The diversity in kind of these spaces is of course infinite; they vary with the mode in which we generalise our conceptions of ordinary space; but upon each as a basis it is possible to construct a consistent system of geometry, whose laws, as a matter of strict reasoning, have a validity and truth not inferior to those with which we are habitually familiar. Such systems having been actually constructed, the question has not unnaturally been asked, whether there is anything in nature or in the outer world to which they correspond; whether, admitting that for our limited experience ordinary geometry amply suffices, we may understand that for powers more extensive in range or more minute in definition some more general scheme would be requisite? Thus, for example, although the one may serve for the solar system, is it legitimate to suppose that it may fail to apply at distances reaching to the fixed stars, or to regions beyond? Or again, if our vision could discern the minute configuration of portions of space, which to our ordinary powers appear infinitesimally small, should we expect to find that all our usual Geometry is but a special case, suffi-

cient indeed for daily use, but after all only a rough approximation to a truer although perhaps more complicated scheme? Traces of these questions are in fact to be found in the writings of some of our greatest and most original mathematicians. Gauss, Riemann, and Helmholtz have thrown out suggestions radiating as it were in these various directions from a common centre; while Cayley, Sylvester, and Clifford in this country, Klein in Germany, Lobatcheffsky in Russia, Bolyai in Hungary, and Beltrami in Italy, with many others, have reflected kindred ideas with all the modifications due to the chromatic dispersion of their individual minds. But to the main question the answer must be in the negative. And, to use the words of Newton, since "Geometry has its foundation in mechanical practice," the same must be the answer until our experience is different from what it now is. And yet, all this notwithstanding, generalised conceptions of space are not without their practical utility. The principle of representing space of one kind by that of another, and figures belonging to one by their analogues in the other, is not only recognised as legitimate in pure mathematics, but has long ago found its application in cartography. In maps or charts, geographical positions, the contour of coasts, and other features, belonging in reality to the Earth's surface, are represented on the flat; and to each mode of representation, or projection as it is called, there corresponds a special correlation between the spheroid and the plane. To this might perhaps be added the method of descriptive geometry, and all similar processes in use by engineers, both military and civil.

It has often been asked whether modern research in the field of Pure Mathematics has not so completely outstripped its physical applications as to be practically useless; whether the analyst and the geometer might not now, and for a long time to come, fairly say, "hic artem remumque repono," and turn his attention to Mechanics and to Physics. That the Pure has outstripped the Applied is largely true; but that the former is on that account useless is far from true. Its utility often crops up at unexpected points; witness the aids to classification of physical quantities, furnished by the ideas (of Scalar and Vector) involved in the Calculus of Quaternions; or the advantages which have accrued to Physical Astronomy from Lagrange's Equations, and from Hamilton's Principle of Varying Action; on the value of Complex Quantities, and the properties of general Integrals, and of general theorems on integration for the Theories of Electricity and Magnetism. The utility of such researches can in no case be discounted, or even imagined beforehand; who, for instance, would have supposed that the Calculus of Forms or the Theory of Substitutions would have thrown much light upon ordinary equations; or that Abelian Functions and Hyperelliptic Transcendents would have told us anything about the properties of curves; or that the Calculus of Operations would have helped us in any way towards the figure of the Earth? But upon such technical points I must not now dwell. If, however, as

I hope, it has been sufficiently shown that any of these more extended ideas enable us to combine together, and to deal with as one. properties and processes which from the ordinary point of view present marked distinctions, then they will have justified their own existence; and in using them we shall not have been walking in a vain shadow, nor disquieting our brains in vain.

These extensions of mathematical ideas would, however, be overwhelming, if they were not compensated by some simplifications in the processes actually employed. Of these aids to calculation I will mention only two, viz., symmetry of form, and mechanical appliances; or, say, Mathematics as a Fine Art, and Mathematics as a Handicraft. And first, as to symmetry of form. There are many passages of algebra in which long processes of calculation at the outset seem unavoidable. Results are often obtained in the first instance through a tangled maze of formulæ, where at best we can just make sure of our process step by step, without any general survey of the path which we have traversed, and still less of that which we have to pursue. But almost within our own generation a new method has been devised to clear this entanglement. More correctly speaking, the method is not new, for it is inherent in the processes of algebra itself, and instances of it, unnoticed perhaps or disregarded, are to be found cropping up throughout nearly all mathematical treatises. By Lagrange, and to some extent also by Gauss, among the older writers, the method of which I am speaking was recognised as a principle; but beside these perhaps no others can be named until a period within our own recollection. The method consists in symmetry of expression. In algebraical formulæ combinations of the quantities entering therein occur and recur; and by a suitable choice of these quantities the various combinations may be rendered symmetrical, and reduced to a few well-known types. This having been done, and one such combination having been calculated, the remainder, together with many of their results, can often be written down at once, without further calculations, by simple permutations of the letters. Symmetrical expressions, moreover, save as much time and trouble in reading as in writing. Instead of wading laboriously through a series of expressions which, although successively dependent, bear no outward resemblance to one another, we may read off symmetrical formulæ, of almost any length, at a glance. A page of such formulæ becomes a picture: known forms are seen in definite groupings; their relative positions, or perspective as it may be called, their very light and shadow, convey their meaning almost as much through the artistic faculty as through any conscious ratiocinative process. Few principles have been more suggestive of extended ideas or of new views and relations than that of which I am now speaking. In order to pass from questions concerning plane figures to those which appertain to space, from conditions having few degrees of freedom to others which have many—in a word, from more restricted to less re-

stricted problems—we have in many cases merely to add lines and columns to our array of letters or symbols already formed, and then read off pictorially the extended theorems.

Next as to mechanical appliances. Mr. Babbage, when speaking of the difficulty of ensuring accuracy in the long numerical calculations of theoretical astronomy, remarked that the science which in itself is the most accurate and certain of all had, through these difficulties, become inaccurate and uncertain in some of its results. And it was doubtless some such consideration as this, coupled with his dislike of employing skilled labour where unskilled would suffice, which led him to the invention of his calculating machines. The idea of substituting mechanical for intellectual power has not lain dormant; for beside the arithmetical machines whose name is legion (from Napier's Bones, Earl Stanhope's calculator, to Schultz and Thomas's machines now in actual use) an invention has lately been designed for even a more difficult task. Prof. James Thomson has in fact recently constructed a machine which, by means of the mere friction of a disk, a cylinder, and a ball, is capable of effecting a variety of the complicated calculations which occur in the highest application of mathematics to physical problems. By its aid it seems that an unskilled labourer may, in a given time, perform the work of ten skilled arithmeticians. The machine is applicable alike to the calculation of tidal, of magnetic, of meteorological, and perhaps also of all other periodic phenomena. It will solve differential equations of the second and perhaps of even higher orders. And through the same invention the problem of finding the free motions of any number of mutually attracting particles, unrestricted by any of the approximate suppositions required in the treatment of the Lunar and Planetary Theories, is reduced to the simple process of turning a handle.

When Faraday had completed the experimental part of a physical problem, and desired that it should thenceforward be treated mathematically, he used irreverently to say, "Hand it over to the calculators." But truth is ever stranger than fiction; and if he had lived until our day, he might with perfect propriety have said, "Hand it over to the machine."

Had time permitted, the foregoing topics would have led me to point out that the mathematician, although concerned only with abstractions, uses many of the same methods of research as are employed in other sciences, and in the arts, such as observation, experiment, induction, imagination. But this is the less necessary because the subject has been already handled very ably, although with greater brevity than might have been wished, by Professor Sylvester in his address to Section A. at our meeting at Exeter.

In an exhaustive treatment of my subject there would still remain a question which in one sense lies at the bottom of all others, and which through almost all time has had an attraction for reflective minds, viz.,

what was the origin of mathematical ideas? Are they to be regarded as independent of, or dependent upon, experience? The question has been answered sometimes in one way and sometimes in another. But the absence of any satisfactory conclusion may after all be understood as implying that no answer is possible in the sense in which the question is put; or rather that there is no question at all in the matter, except as to the history of actual facts. And, even if we distinguish, as we certainly should, between the origin of ideas in the individual and their origin in a nation or mankind, we should still come to the same conclusion. If we take the case of the individual, all we can do is to give an account of our own experience; how we played with marbles and apples; how we learnt the multiplication table, fractions, and proportion; how we were afterwards amused to find that common things conformed to the rules of number; and later still how we came to see that the same laws applied to music and to mechanism, to astronomy, to chemistry, and to many other subjects. And then, on trying to analyse our own mental processes, we find that mathematical ideas have been imbibed in precisely the same way as all other ideas, viz., by learning, by experience, and by reflexion. The apparent difference in the mode of first apprehending them and in their ultimate cogency arises from the difference of the ideas themselves. from the preponderance of quantitative over qualitative considerations in mathematics, from the notions of absolute equality and identity which they imply.

If we turn to the other question, How did the world at large acquire and improve its idea of number and of figures? How can we span the interval between the savage who counted only by the help of outward objects, to whom 15 was "half the hands and both the feet," and Newton or Laplace? The answer is the history of mathematics and its successive developments, arithmetic, geometry, algebra, &c. The first and greatest step in all this was the transition from number in the concrete to number in the abstract. This was the beginning not only of mathematics but of all abstract thought. The reason and mode of it was the same as in the individual. There was the same general influx of evidence, the same unsought-for experimental proof, the same recognition of general laws running through all manner of purposes and relations of life. No wonder then if, under such circumstances, mathematics, like some other subjects and perhaps with better excuse, came after a time to be clothed with mysticism; nor that, even in modern times, they should have been placed upon an *à priori* basis, as in the philosophy of Kant. Number was so soon found to be a principal common to many branches of knowledge that it was readily assumed to be the key to all. It gave distinctness of expression, if not clearness of thought, to ideas which were floating in the untutored mind, and even suggested to it new conceptions. In "the one," "the all," "the many in one," (terms of purely arithmetic origin,) it gave the earliest utterance to men's first crude notions about God and the world. In "the equal," "the solid," "the straight," and "the crooked,"

which still survive as figures of speech among ourselves, it supplied a vocabulary for the moral notions of mankind, and quickened them by giving them the power of expression. In this lies the great and enduring interest in the fragments which remain to us of the Pythagorean philosophy.

The consecutive processes of Mathematics led to the consecutive processes of Logic; but it was not until long after mankind had attained to abstract ideas that they attained to any clear notion of their connexion with one another. In process of time the leading ideas of Mathematics became the leading ideas of Logic. The "one" and the "many" passed into the "whole" and its "parts;" and thence into the "universal" and the "particular." The fallacies of Logic, such as the well-known puzzle of Achilles and the tortoise, partake of the nature of both sciences. And perhaps the conception of the infinite and the infinitesimal, as well as of negation, may have been in early times transferred from Logic to Mathematics. But the connexion of our ideas of number is probably anterior to the connexion of any of our other ideas. And as a matter of fact, geometry and arithmetic had already made considerable progress when Aristotle invented the syllogism.

General ideas there were, beside those of mathematics—true flashes of genius which saw that there must be general laws to which the universe conforms, but which saw them only by occasional glimpses, and through the distortion of imperfect knowledge; and although the only records of them now remaining are the inadequate representations of later writers, yet we must still remember that to the existence of such ideas is due not only the conception but even the possibility of Physical Science. But these general ideas were too wide in their grasp, and in early days at least were connected to their subjects of application by links too shadowy, to be thoroughly apprehended by most minds; and so it came to pass that one form of such an idea was taken as its only form, one application of it as the idea itself; and philosophy, unable to maintain itself at the level of ideas, fell back upon the abstractions of sense, and, by preference, upon those which were most ready to hand, namely, those of mathematics. Plato's ideas relapsed into a doctrine of numbers; mathematics into mysticism, into neo-Platonism, and the like. And so, through many long ages, through good report and evil report, mathematics have always held an unsought-for sway. It has happened to this science as to many other subjects, that its warmest adherents have not always been its best friends. Mathematics have often been brought into matters where their presence has been of doubtful utility. If they have given precision to literary style, that precision has sometimes been carried to excess, as in Spinoza and perhaps Descartes; if they have tended to clearness of expression in philosophy, that very clearness has sometimes given an appearance of finality not always true; if they have contributed to definition in theology, that definiteness has often been fictitious, and has been attained at the cost of spiritual meaning. And, coming to recent times, although we

may admire the ingenuity displayed in the logical machines of Earl Stanhope and of Stanley Jevons, in the 'Formal Logic' of De Morgan, and in the 'Calculus' of Boole; although as mathematicians we may feel satisfaction that these feats (the possibility of which was clear *à priori*) have been actually accomplished; yet we must bear in mind that their application is really confined to cases where the subject-matter is perfectly uniform in character, and that beyond this range they are liable to encumber rather than to assist thought.

Not unconnected with this intimate association of ideas and their expression is the fact that, whichever may have been cause, whichever effect, or whether both may not in turn have acted as cause and effect, the culminating age of classic art was contemporaneous with the first great development of mathematical science. In an earlier part of this discourse I have alluded to the importance of mathematical precision recognised in the technique of art during the Cinquecento; and I have now time only to add that on looking still further back it would seem that sculpture and painting, architecture and music, nay even poetry itself, received a new, if not their first true, impulse at the period when geometric form appeared fresh chiselled by the hand of the mathematician, and when the first ideas of harmony and proportion rang joyously together in the morning tide of art.

Whether the views on which I have here insisted be in any way novel, or whether they be merely such as from habit or from inclination are usually kept out of sight, matters little. But whichever be the case, they may still furnish a solvent of that rigid aversion which both Literature and Art are too often inclined to maintain towards Science of all kinds. It is a very old story that, to know one another better, to dwell upon similarities rather than upon diversities, are the first stages towards a better understanding between two parties; but in few cases has it a truer application than in that here discussed. To recognise the common growth of scientific and other instincts until the time of harvest is not only conducive to a rich crop, but it is also a matter of prudence, lest in trying to root up weeds from among the wheat, we should at the same time root up that which is as valuable as wheat. When Pascal's father had shut the door of his son's study to mathematics, and closeted him with Latin and Greek, he found on his return that the walls were teeming with formulæ and figures, the more congenial product of the boy's mind. Fortunately for the boy, and fortunately also for Science, the mathematics were not torn up, but were suffered to grow together with other subjects. And all said and done, the lad was not the worse scholar or man of letters in the end. But, truth to tell, considering the severance which still subsists in education and during our early years between Literature and Science, we can hardly wonder if when thrown together in the afterwork of life they should meet as strangers; or if the severe garb, the curious implements, and the strange wares of the latter

should seem little attractive when contrasted with the light companionship of the former. The day is yet young, and in the early dawn many things look weird and fantastic which in fuller light prove to be familiar and useful. The outcomings of Science, which at one time have been deemed to be but stumbling-blocks scattered in the way, may ultimately prove stepping stones which have been carefully laid to form a pathway over difficult places for the children of "sweetness and of light."

The instances on which we have dwelt are only a few out of many in which Mathematics may be found ruling and governing a variety of subjects. It is as the supreme result of all experience, the framework in which all the varied manifestations of nature have been set, that our science has laid claim to be the arbiter of all knowledge. She does not indeed contribute elements of fact, which must be sought elsewhere; but she sifts and regulates them: she proclaims the laws to which they must conform if those elements are to issue in precise results. From the data of a problem she can infallibly extract all possible consequences, whether they be those first sought, or others not anticipated; but she can introduce nothing which was not latent in the original statement. Mathematics cannot tell us whether there be or be not limits to time or space; but to her they are both of indefinite extent, and this in a sense which neither affirms nor denies that they are either infinite or finite. Mathematics cannot tell us whether matter be continuous or discrete in its structure; but to her it is indifferent whether it be one or the other, and her conclusions are independent of either particular hypothesis. Mathematics can tell us nothing of the origin of matter, of its creation or its annihilation; she deals only with it in a state of existence; but within that state its modes of existence may vary from our most elementary conception to our most complex experience. Mathematics can tell us nothing beyond the problems which she specifically undertakes; she will carry them to their limit, but there she stops, and upon the great region beyond she is imperturbably silent.

Conterminous with space and coëval with time is the kingdom of Mathematics; within this range her dominion is supreme; otherwise than according to her order nothing can exist; in contradiction to her laws nothing takes place. On her mysterious scroll is to be found written for those who can read it that which has been, that which is, and that which is to come. Everything material which is the subject of knowledge has number, order, or position; and these are her first outlines for a sketch of the universe. If our more feeble hands cannot follow out the details, still her part has been drawn with an unerring pen, and her work cannot be gainsaid. So wide is the range of mathematical science, so indefinitely may it extend beyond our actual powers of manipulation, that at some moments we are inclined to fall down with even more than reverence before her majestic presence. But so strictly limited are her promises and powers, about so much that we might wish to know does she offer no

information whatever, that at other moments we are fain to call her results but a vain thing, and to reject them as a stone when we had asked for bread. If one aspect of the subject encourages our hopes, so does the other tend to chasten our desires; and he is perhaps the wisest, and in the long run the happiest among his fellows, who has learnt not only this science, but also the larger lesson which it indirectly teaches, namely, to temper our aspirations to that which is possible, to moderate our desires to that which is attainable, to restrict our hopes to that of which accomplishment, if not immediately practicable, is at least distinctly within the range of conception. That which is at present beyond our ken may, at some period and in some manner as yet unknown to us, fall within our grasp; but our science teaches us, while ever yearning with Goethe for "Light, more light," to concentrate our attention upon that of which our powers are capable, and contentedly to leave for future experience the solution of problems to which we can at present say neither yea nor nay.

It is within the region thus indicated that knowledge in the true sense of the word is to be sought. Other modes of influence there are in society and in individual life, other forms of energy beside that of intellect. There is the potential energy of sympathy, the actual energy of work; there are the vicissitudes of life, the diversity of circumstance, health, and disease, and all the perplexing issues, whether for good or for evil, of impulse and of passion. But although the book of life cannot at present be read by the light of Science alone nor the wayfarers be satisfied by the few loaves of knowledge now in our hands; yet it would be difficult to overstate the almost miraculous increase which may be produced by a liberal distribution of what we already have, and by a restriction of our cravings within the limits of possibility.

In proportion as method is better than impulse, deliberate purpose than erratic action, the clear glow of sunshine than irregular reflexion, and definite utterances than an uncertain sound; in proportion as knowledge is better than surmise, proof than opinion; in that proportion will the mathematician value a discrimination between the certain and the uncertain, and a just estimate of the issues which depend upon one motive power or the other. While on the one hand he accords to his neighbours full liberty to regard the unknown in whatever way they are led by the noblest powers that they possess; so on the other he claims an equal right to draw a clear line of demarcation between that which is a matter of knowledge, and that which is at all events something else, and to treat the one category as fairly claiming our assent, the other as open to further evidence. And yet, when he sees around him those whose aspirations are so fair, whose impulses so strong, whose receptive faculties so sensitive, as to give objective reality to what is often but a reflex from themselves, or a projected image of their own experience, he will be willing to admit that there are influences which he cannot as yet either fathom or measure, but whose operation he must recognise among the facts of our existence.

NOTES.

Page 6, line 10. It is worth while to compare the following passage from Plato's 'Republic,' Book vii. (Jowett's translation):

"After plane geometry, we took solids in revolution instead of taking solids in themselves; whereas after the second dimension the third, which is concerned with cubes and dimensions of depth, ought to have been followed.

"It is true, Sociates; but these subjects seem to be as yet hardly explored.

"Why, yes, I said, and for two reasons; in the first place, no government patronises them, which leads to a want of energy in the study of them, and they are difficult; in the second place, students cannot learn them unless they have a teacher. But then a teacher is hardly to be found, and even if one could be found, as matters now stand the students of these subjects, who are very conceited, would not mind him; that, however, would be otherwise if the whole state patronised and honoured them, then they would listen, and there would be continuous and earnest search, and discoveries would be made; since even now, disregarded as they are by the world, and maimed of their fair proportions, and although none of their votaries can tell the use of them, still these studies force their way by their natural charm, and very likely they may emerge into light."

P. 11, l. 44. Compare with this the latter part of Plato's 'Philebus,' on knowledge and the handicraft arts; also Prof. Jowett's 'Introduction' thereto.

P. 13, l. 40. See 'Trattato della Pittura,' by Leonardo da Vinci; also the 'Memoir on the MSS. of L. d. V.,' by Venturi, 1797.

P. 14, l. 2. 'The Gentleman and Cabinet Maker's Director,' by Thomas Chippendale, London, 1754.

'The Cabinet Maker and Upholsterer's Drawing Book,' by Thomas Sheraton, London, 1793.

P. 14, l. 32. See Sorby's 'Address to the Microscopical Society,' 1876.

P. 14, l. 38. 'Phil. Trans. of the Royal Society,' 1870, p. 333; and 1876, p. 27.

P. 14, l. 42. 'Phil. Trans.,' 1877, p. 149.

P. 15, l. 6. 'On Attraction and Repulsion resulting from Radiation,' 'Phil. Trans.,' 1874, p. 501; 1875, p. 519; 1876, p. 325.

P. 15, l. 9. 'Philosophical Magazine,' April, 1878.

P. 15, l. 10. 'Philosophical Magazine,' 1875, Vol. ii., pp. 337, 446; 187 Vol. i., p. 321; 1878, Vol. i., p. 161.

P. 15, l. 20. Poggendorff's 'Annalen,' Tom. xxxv., p. 337.

P. 15, l. 21. 'Royal Society's Proceedings,' 1878.

P. 15, l. 28. The Papers on the Telephone are too numerous to specify.

P. 15, l. 29. See various Papers in 'Nature,' and elsewhere, during the last twelve months.

Page 15, line 23. 'Royal Society's Proceedings,' May 9, 1878.

P. 15, l. 33. 'Phil. Trans.,' Vol. 169, pp. 55 and 155, and other Papers catalogued in the 'Appendix to Part II. of the Memoir.'

Page 16, line 25. See Maxwell 'On Heat,' chap. xxii.

P. 17, l. 29. Grunert's 'Archiv,' Vol. vi., p. 337; also separate work, Berlin, 1862.

P. 17, l. 31. 'Linear Associative Algebra,' by Benjamin Peirce, Washington City, 1870.

P. 18, l. 10. Sir W. Thomson, 'Cambridge Mathematical Journal,' Vol. iii., p. 174. Jevons' 'Principles of Science,' Vol. ii., p. 438.
But an explanation of the difficulty seems to me to be found in the fact that the problem, as stated, is one of the conduction of heat, and that the "impossibility" which attaches itself to the expression for the "time" merely means that previous to a certain epoch the conditions which gave rise to the phenomena were not those of conduction, but those of some other action of heat. If, therefore, we desire to comprise the phenomena of the earlier as well as of the later period in one problem we must find some more general statement, viz., that of physical conditions which at the critical epoch will issue in a case of conduction. I think that Prof. Clifford has somewhere given a similar explanation.

P. 21, l. 13. S. Newcomb 'On Certain Transformations of Surfaces,' 'American Journal of Mathematics,' Vol. i., p. 1.

P. 21, l. 14. Tait 'On Knots,' 'Transactions of the Royal Society of Edinburgh,' Vol. xxviii., p. 145; Klein, 'Mathematische Annalen,' ix., p. 478.

P. 27, l. 18. 'Royal Society's Proceedings,' February 3, 1876, and May 9, 1878.

P. 30, l. 1. For example, in Herbart's 'Psychologie.'

P. 30, l. 3. A specimen will be found in the 'Moralia' of Gregory the Great, Lib. I. c. xiv., of which I quote only the arithmetical part:
"Quid in septenario numero, nisi summa perfectionis accipitur? Ut enim humanæ rationis causas de septenario numero taceamus, quæ afferunt, quòd idcirco perfectus sit, quia exprimo pari constat, et primo, impari; ex primo, qui dividi potest, et primo, qui dividi non potest; certissimè scimus, quòd septenarium numerum Scriptura Sacra pro perfectione ponere consuevit. . . . . A septenario quippe numero in duodenarium surgitur. Nam septenarius suis in se partibus multiplicatus, ad duodenarium tenditur. Sive enim quatuor per tria, sive per quatuor tria ducantur, septem in duodecim vertuntur. . . . Jam superiùs dictum est quòd in quinquagenario numero, qui septem hebdomadibus ac monade additâ impletur, requies designatur; denario autem numero summa perfectionis exprimetur."

P. 30, l. 16. Approximate dates B.C. of—

Sculptors, Painters, and Poets.		Mathematicians.	
Stesichorus,	600.	Thales,	600.
Pindar,	522–442.	Pythagoras,	550.
Æschylus,	500–450.	Anaxagoras,	500-450.
Sophocles,	495–400.	Hippocrates,	460.
Euripides,	480–400.		
Phidias,	488–432.		
Praxiteles,	450–400.	Theætetus,	440.
Zeuxis,	400.	Archytas,	400.
Apelles,	350.		
Scopas,	350.	Euclid,	323-283.

REPORTS

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Catalogue of the Oscillation-frequencies of Solar Rays; drawn up under the superintendence of a Committee of the British Association, consisting of Dr. HUGGINS (*Chairman*), Dr. DE LA RUE, Mr. J. NORMAN LOCKYER, Dr. J. EMERSON REYNOLDS, Mr. SPOTTISWOODE, Dr. W. MARSHALL WATTS, *and* Mr. G. JOHNSTONE STONEY (*Reporter*) *.

EVERY periodic disturbance of the ether which can be propagated through it as an undulation may be represented mathematically by one or more terms of the harmonic expansion known as Fourier's series. A single term of this series suffices to represent the undulation when the waves are of that simplest type which can be represented by a curve of sines—the curve which represents the small oscillations of a pendulum. But when the waves are of a more complicated form, two or more terms, perhaps all the terms. of the series must be retained in order to represent it; and in such cases the terms of the series which remain severally represent the simple sinusoid or pendulous undulations, which, if made to coexist in the medium by being piled on one another, would become identical with the actual complex undulation which is present in it.

The non-periodic disturbances which traverse a medium are of two kinds—those which, like the clang of a bell, may be represented by a series consisting of sinusoid terms with distinct periodic times, though in this case not harmonically, or at least not all harmonically, related; and those which can be decomposed into sinusoid elements only under the condition that the elementary undulations have periodic times which pass without hiatus into one another.

Now so long as light is propagated through what is called a vacuum, the undulation, however complex, maintains its form unaltered at all distances from the source of light; for in vacuous spaces waves of different periods advance at the same rate and directly forwards, and therefore the simple component undulations which are represented by the several terms of a

* A Map of Oscillation-frequencies is in preparation, and will be presented to the British Association at the Meeting at Sheffield in 1879.

sinusoid series accurately accompany each other throughout their whole journey.

But the event is different if the light encounters an optical agent which acts differently on waves of different periods. Of this kind are the prisms and diffraction-gratings of our spectroscopes. Here Nature herself effects the decomposition which is indicated by the theory. Waves of different periods are compelled to travel in different directions, and thus the several terms of the sinusoid series appear under the form of lines in the spectrum. The wave-lengths corresponding to each position in the spectrum have been determined with great care, and these when corrected for the dispersion of the air are proportional to the corresponding periodic times, which thus become known. Moreover, the intensities of the lines may be observed, and will give the coefficients to be applied to the corresponding terms of the sinusoid series. Hence by a discussion of the observations we may expect to learn much with regard to the original disturbance caused by the source of light. Non-periodic disturbances of the second class will be indicated by continuous spectra, while the other two classes of disturbances will be distinguished by spectra which consist of separate rays; and a careful study of the positions and intensities of the rays may give valuable information as to the periodic time, and sometimes even as to the particular form of the original disturbance.

Hence in the present state of science it is of importance to facilitate this inquiry as much as possible; and it is hoped that aid will be given to the student of nature by the Table now published, in which the oscillation-frequencies of the principal rays of the visible part of the solar spectrum have been computed from Ångström's admirable determinations of their wave-lengths in air, combined with Ketteler's observations on the dispersion of air. Such a table and its accompanying map afford the most assistance that can be given towards the detection of harmonic relations; for rays that are harmonically related are therein represented in the simplest form that is practicable—in the Table by an arithmetic series of the same type as the series of natural numbers, where the common difference is equal to the first term; and in the Map by a series of equidistant lines.

While this theoretic advantage has been the guiding aim of the Committee, they have also kept constantly in view the convenience of observers. A map of Oscillation-frequencies offers peculiar facilities for this, as its red end is less extended when compared with its blue end than in Ångström's map and more extended than in Kirchhoff's. It thus delineates the spectrum with an appearance intermediate between that of a diffraction spectrum and that of a prismatic spectrum, and does not distort either spectrum too much for practical use. It may thus be employed without inconvenience by observers with either of the two great classes of spectroscope. The Committee are accordingly occupied in preparing such a Map to accompany the Table.

The Committee were of opinion that it would prove a boon to observers to have Kirchhoff's, Ångström's, and the new numbers in reference to each ray brought together in one horizontal line. Before this could be accomplished it was necessary to make a systematic comparison of Ångström's numbers and maps with Kirchhoff's, and of both with the actual solar spectrum, in order to identify the rays wherever practicable.

The Committee therefore felt that it was desirable that this work should be undertaken; and it has been satisfactorily accomplished by Charles E. Burton, Esq., B.A., F.R.A.S., who has made all observations and computations required by the Committee. He has, moreover, inserted (in brackets) in column 2 the

wave-lengths of those rays of Kirchhoff's list which are not found in Ångstrom's, wherever it appeared possible to make the interpolation with safety.

The small corrections which Ångström indicates at p. 29 of his memoir ('Le Spectre Normal du Soleil') have been applied to his numbers before inserting them in column 2. Accordingly the numbers of this column which are not in brackets represent Ångstrom's work in its finished state.

In column 6 the intensities and widths which Kirchhoff assigns to rays between A and G have been reproduced; and Mr. Burton has continued these determinations to all the rays recorded by Ångström between G and H, so that they now cover the whole spectrum from A to H. Before entering on this work Mr. Burton prepared himself by a revision of portions of the spectrum which Kirchhoff had delineated, so as to ensure that he should employ Kirchhoff's symbols in the same sense in which they had been used by Kirchhoff and his assistant Hofmann.

And in the last column Mr. Burton has thrown the solar rays into such groups as appeared to him to be the most convenient to an observer. It will probably be possible to improve this part of the work, if a second edition of the Catalogue is called for.

In columns 3 and 4 are given the steps by which the oscillation-frequencies of the rays have been computed from their wave-lengths, in order that it may be easy to revise the former if improvements are at any time made upon Ångström's table of wave-lengths, or on the values for the refraction of air which have been used.

The Map which the Committee are engaged in preparing will be a mere chart, in which the intensities of the rays will be indicated by lines of different lengths. It does not appear to the Committee to be desirable that they should attempt a finished drawing of the Solar Spectrum in the present state of spectroscopic science, in which observers may hope soon to have in their hands good photographs of every part of the visible spectrum. In order meanwhile to supply as far as possible the place of a more finished map, tables will be appended which will enable any one who possesses Kirchhoff's exquisite map or Ångström's to place upon them the outlines of a scale of oscillation-frequencies, so as to make these maps in a large degree available.

The Committee will feel obliged to any spectroscopists who are so good as to send to G. Johnstone Stoney, 3 Palmerston Park, Dublin, such corrections of the present tables as may occur to them, with a view to their insertion in future editions.

CATALOGUE *of the principal Dark Rays of the visible part of the Solar Spectrum, containing all the rays registered by* KIRCHHOFF *and* ÅNGSTRÖM, *arranged on a scale of* OSCILLATION-FREQUENCIES.

EXPLANATION.

Column 1 gives the position on the Arbitrary Scale attached to Kirchhoff's maps.

Column 2 reproduces the wave-lengths in tenth-metres as determined by Ångström, after applying to the numbers of Ångström's list the small corrections which he indicates at p. 29 of his memoir, "Le Spectre Normal du Soleil." The wave-lengths of rays recorded by Kirchhoff, but not by Angstrom, have been introduced within brackets

into this column wherever it appeared that the interpolation could be made with sufficient safety. The wave-lengths of this list are wave-lengths in air of 760 millims. pressure at Upsala and 16° C. temperature.

Column 3 contains the reciprocals of the numbers in column 2, each multiplied by 10^7. Each number in this column may accordingly be regarded either as the number of times that the corresponding wave-length-in-air goes into one millimetre, or as the number of complete oscillations in the time $\mu\tau$, where μ is the index of refraction of air for that ray.

Column 4 contains the correction for the dispersion of air of 760 millims. pressure and 16° temperature, deduced from Ketteler's observations. (See 'Philosophical Magazine' for 1866, vol. ii. p. 336.)

Column 5 gives the OSCILLATION-FREQUENCY of each ray in the time τ, the time that light takes to advance one millimetre *in vacuo*. Or the numbers of this column may be regarded as the numbers of waves per millimetre *in vacuo*.

Column 6 indicates the intensity and width of each ray between A and G, as determined by Kirchhoff, and between G and H_2, as determined by Mr. Burton, 6 being the most intense and *g* being very wide, viz. about 0·15 of one degree of the scale of oscillation-frequencies.

Column 7 enumerates the substances which have been found to emit bright rays coincident with dark solar rays, and contains some other remarks.

Column 8. In the last column the rays are bracketed into the groups which strike the eye in looking at the spectrum, and to each group is assigned a number which sufficiently indicates its position upon the standard scale.

Position on Kirchhoff's Arbitrary Scale.	Ångström's wave-lengths in air.	Reciprocals.	Correction for the dispersion of the air.	Oscillation-frequency in the time τ.	Intensity and width.	Origin, &c.	Groups of rays.
...	7604·0	1315·10	0·36	1314·74	...	A.	
...	7315·1	67·03	0·38	1366·65	...	Kirchhoff records 57 rays less refrangible than 480·1 (see Appendix I.), but none of them have been identified with these rays of Ångström's.	
...	7307·4	68·48	„	1368·10	...		
...	7300·4	69·79	„	1369·41	...		
...	7289·7	71·80	„	1371·42	...		
...	7285·7	72·55	„	1372·17	...		
480·1	7274·4	74·68	„	1374·30	6 c		
480·4	(7271·3)	75·3	„	1374·9	4 d		
481·2	7262·1	77·01	„	1376·63	4 c		
482·1	(7260·5)	77·3	„	1376·9	2 d		
483·3	(7258·3)	77·7	„	1377·3	4 d		
484·1	7256·9	78·00	„	1377·62	2 d		
485·1	(7253·4)	78·7	„	1378·3	3 d		
486·2	7249·5	79·40	„	1379·02	6 e		
486·3	(7248·3)	79·6	„	1379·2	2 c		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
488·2 to 488·8	... 7241·9	... 1380·85	... 0·38	.. 1380·47	1 5 a		
489·6	7237·5	81·69	„	1381·31	6 c		
491·2 491·5 491·9	7230 3	83·07	„	1382·69	3 e 5 b 4 c		
493·1	7224·8	84·12	„	1383·74	2 c		
494·1	7219·9	85·06	„	1384·68	3 b		
495·4	(7214·6)	86·1	„	1385·7	1 e		
495·7	7213 4	86·31	„	1385·93	2 b		
497·2	(7208 5)	87·3	„	1386·9	1 b		
497·5	(7207 5)	87·4	„	1387·0	2 a		
498·4	7204·6	88·00	„	1387 62	4 c		Group 1392 (the *a* Group). Strong.
499·0	7202·5	88·41	„	1388·03	5 b		
499·9	7198 1	89·25	„	1388·87	5 d		
500·8	7195 6	89·74	„	1389·36	3 d		
501·8	(7191·8)	90·5	„	1390·1	2 c		
502·0	7191·0	90·63	„	1390 25	5 b		
502·6	7189·3	90·96	„	1390·58	5 c		
503·8	7184·7	91·85	0·38	1391·47	6 d		
504·3	7182·5	92·27	0·39	1391·88	5 b		
505·1	7179·2	92·91	„	1392·52	6 c		
506·2	7175·7	93·59	„	1393 20	2 b		
506·4	(7175·0)	93·7	„	1393·3	5 b		
506·6	(7143·3)	93·9	„	1393 5	2 b		
507·4	7171·3	94·45	„	1394·06	5 c		
508·2	(7164·5)	95·8	„	1395·4	3 b		
509·1	7163·0	96·06	„	1395·67	3 b		
509·9	7160·2	96·61	„	1396·22	2 b		
510·9	(7156·4)	97·4	„	1397 0	1 a		
512·9	(7148·7)	98·9	„	1398·5	2 b		
513·6	7146·0	1399·38	„	1398·99	3 b	Fe.	
517·1	(7133·3)	1401·9	„	1401·5	2 b		
519·3	(7125·3)	03·5	„	1403·1	2 b		
521·6	(7116·9)	05·1	„	1404·7	1 b		
529·4	(7088·6)	10·7	„	1410·3	1 b		
530·4	(7085·0)	11·4	„	1411 0	1 c		

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Grou
532·8	(7075·8)	1413·3	0·39	1412·9	1 b		
536·9	(7061·3)	16·2	„	1415·8	2 b		
537·3	(7059 9)	16·5	„	1416 1	1 b		
540·6	7047·9	18·86	„	1418·47	3 b		
541·1	(7045·6)	19·3	„	1418·9	2 c		
542·0	(7041·4)	20 2	„	1419·8	1 a		
543·6	7034·0	21·67	„	1421·28	4 b		
544·6	(7031·3)	22·2	„	1421·8	3 d		
547·0	7025 0	23·49	„	1423·10	4 c		
547·9	7021·6	24·18	„	1423·79	2 b		
549·6	7014·2	25·68	„	1425·29	3 e		
551·2	7009 0	26·74	0·39	1426·35	3 c		
552·5	7003·4	27·88	0·40	1427·48	3 c		
(553·8	(6998·3)	28·9	„	1428·5	1 c		
(554·0	6997·5	29·08	„	1428·68	3 b		
554·6	(6995·0)	29·6	„	1429·2	2 b		
...	6992·5	30·10	„	1429·70	...		
...	6987·2	31·19	„	1430·79	...		
557·0	6984 3	31·78	„	1431·38	1 a		
557·7	(6981 8)	32·3	„	1431·9	2 b		
558·1	(6980·1)	32·6	„	1432·2	1 b		
559·7	(6973·4)	34·0	„	1433·6	1 c		
...	6969·5	34·82	„	1434·42	...		
561·5	(6965·7)	35·6	„	1435·2	1 b		
...	6964·3	35·89	„	1435·49	...		
562·5	(6961·5)	36·5	„	1436·1	3 b		
...	6962·3	36·31	„	1435·91	...		
563·0	6959·7	36·84	„	1436·44	2 c		
...	6957·5	37·30	„	1436·90	...		
564·1	6954·7	37·88	„	1437·48	4 c		
565·0	6951·7	38·50	„	1438·10	2 c		
566·0	6949·3	38·99	„	1438·59	2 c		
566·9	...	...	...	...	2 b		
567·4	6945·8	39·72	„	1439·32	3 b		
568·6	6941·7	40·57	„	1440·17	2 b		
to	...	...	...	...	1		
569·2	6940·5	40·82	„	1440·42	2 b	Winged ray.	
to	...	...	...	...	1		
570·0	6938·6	41·21	„	1440·81	3 c		
570·6	6936·4	41·67	„	1441·27	2 b		

CATALOGUE (*continued*).

Kirchhoff.	Ång-ström.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
572·2	6932·1	1442·56	0·40	1442·16	3 b		
572·9	(6930·0)	43·0	„	1442·6	1 b		
573·6	6927·9	43·44	„	1443·04	3 c		
574·4	(6926·0)	43·8	„	1443·4	1 b		
575·1	6922·4	44·59	„	1444·19	2 d		
576·6	6917·1	45·69	„	1445·29	2 d		
578·1	6912·1	46·74	„	1446·34	3 d		
579·6	6907·8	47·64	„	1447·24	3 d		Group 145((the B Group. Very strong atmospheric
581·1	6903·2	48·60	„	1448·20	3 e		
582·5	6899·0	49·48	„	1449·08	3 e		
583·8	(6895·0)	50·3	„	1449·9	4 e		
585·0	6891·4	51·08	„	1450·68	4 f		
586·2	6888·3	51·74	„	1451·34	4 e		
587·0	6885·0	52·43	„	1452·03	3 e		
587·9	6882·6	52·94	„	1452·54	2 b		
589·0	6878·5	53·80	„	1453·40	3 b		
589·4	6876·2	54·29	„	1453·89	3 b		
589·9	(6875·0)	54·5	„	1454·1	3 b		
590·3	(6874·0)	54·8	„	1454·4	3 b		
590·7	(6873·0)	55·0	„	1454·6	3 b		
591·1	(6872·0)	55·2	„	1454·8	3 b		
591·5	6871·0	55·39	„	1454·99	4 b		
591·9	6869·9	55·62	„	1455·22	4 b		
592·3	...	...	...	...	3 b		
592·7	6867·1	56·22	„	1455·82	6 c	B.	
593·1	(6866·2)	56·4	„	1456·0	4 g		
595·0	(6861·8)	57·3	„	1456·9	1 a		
596·6	(6858·1)	58·1	„	1457·7	1 a		
597·4	6856·3	58·51	0·40	1458·11	1 b		
601·2	(6843·8)	61·2	0·41	1460·8	1 a		
601·8	(6841·8)	61·6	„	1461·2	1 b		
602·8	(6838·5)	62·3	„	1461·9	1 a		
606·0	6828·0	64·56	„	1464·15	1 b		Group 1466. Faint.
608·3	6819·0	66·49	„	1466·08	1 a		
612·4	(6806·3)	69·2	„	1468·8	1 b		
613·4	(6803·1)	69·9	„	1469·5	1 a		
...	6788·7	73·04	„	1472·63	...		

CATALOGUE (*continued*).

Kirchhoff.	Ång-ström.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Group
623·4	(6771·9)	1476·7	0·41	1476·3	1 b		
626·1	6763·5	78·52	"	1478·11	1 b		
631·4	(6761·9)	78·9	"	1478·5	1 b		
...	6761·2	79·03	"	1478·62	...		
638·4	6726·5	86·66	"	1486·25	1 b	Ca.	
639·8	(6721·0)	87·9	"	1487·5	1 b		
641·0	6717·16	88·72	"	1488·31	2 b	Ca.	
...	6713·8	89·47	"	1489·06	...		
645·3	(6704·5)	91·5	"	1491·1	1 b		
...	6703·0	91·87	"	1491·46	...		
...	6701·0	92·31	0·41	1491·90	...		
648·1	...	...	...	...	1 b		
654·3	6677·6	1497·54	0·42	1497·12	2 b		
659·3	6663·1	1500·80	"	1500·38	2 a	Fe.	
...	6659·9	01·52	"	1501·10	...	Identification of Ång-ström's ray with Kirch-hoff's doubtful.	
665·7	6643·1	05·32	"	1504·90	2 a		
669·5	6633·3	07·54	"	1507·12	2 b		
678·6	6604·1	14·21	"	1513·79	1 b	Fe.	
681·4	6597·6	15·70	"	1515·28	1 a		
682·8	6593·3	16·69	"	1516·27	1 b		
683·1	6592·6	16·85	"	1516·43	2 a	Fe.	
685·3	6585·9	18·39	"	1517·97	1 b		
...	6580·6	19·62	"	1519·20	...		
689·8	6574·0	21·14	"	1520·72	2 b	Fe.	
690·9	6571·4	21·75	"	1521·33	1 a		
692·1	6567·9	22·56	"	1522·14	2 a		
693·4 to	...	...	...	...	1	C, H, Air.	
694·1	6562·10	23·90	"	1523·48	6 e		
to 694·8	...	...	...	...	1		
...	6559·79	24·44	"	1524·02	...		
...	6558·42	24·75	"	1524·33	...		
...	6557·58	24·95	"	1524·53	...		
...	6556·19	25·27	"	1524·85	...		
...	6551·78	26·30	"	1525·88	...		
698·1	6550·07	26·70	"	1526·28	2 a		
700·0	6547·86	27·22	"	1526·80	2 a		
701·1	6545·40	27·79	"	1527·37	2 b	Fe.	
702·1	6543·23	28·29	"	1527·87	2 a		

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width	Origin, &c.	Groups.
702·6	6541·45	1528·71	0·42	1528·29	1 b		
...	6536·23	29·93	„	1529·51	...		
705·5	6533·22	30·64	„	1530·22	2 a		
705·9	6531·74	30·98	„	1530·56	2 a		
707·5	(6526·6)	32·2	0·42	1531·8	1 b		
708·6	6523·14	33·00	0·43	1532·57	2 b		
710·5	6518·55	34·08	„	1533·65	2 e		
...	6517·59	34·31	„	1533·88	...		
711·4	6515·80	34·73	„	1534·30	3 c		
712·0	6514·17	35·11	„	1534·68	2 b		
713·2	(6512·9)	35·4	„	1535·0	1 b		
714·4	6511·64	35·71	„	1535·28	1 c		
...	6501·79	38·04	„	1537·61	...		
717·8	6498·25	38·88	„	1538·45	2 b	Ca.	Group 1539. Strong.
718·7 to 719·6	6496·31	39·34	„	1538·91	2	Ba.	
	...	...	...	...	3 a		
...	6495·12	39·62	„	1539·19	...		
...	6494·18	39·84	„	1539·41	...	Fe.	
...	6493·00	40·12	„	1539·69	...		
720·1	6492·41	40·26	„	1539·83	2 e	Ca.	
721·1	6490·07	40·81	„	1539·38	2 b	Fe.	
...	6488·68	41·14	„	1540·71	...		
723·7	6482·79	42·55	„	1542·12	2 c	Appears to be the mean of two rays.	
724·2	6481·18	42·93	„	1542·50	1 b		
725·1	6479·01	43·45	„	1543·02	1 b	Air.	
726·7	6474·85	44·44	„	1544·01	3 c		
727·8	6471·85	45·15	„	1544·72	1 c		
728·0	(6471·3)	45·3	„	1544·9	2 a		
...	6470·75	45·42	„	1544·99	...		
729·0	6468·78	45·89	„	1545·46	2 b	Ca.	
...	6467·14	46·28	„	1545·85	...		
...	6463·74	47·09	„	1546·66	...		
731·7	6461·98	47·51	„	1547·08	5 b	Ca, Fe.	
734·0	...	...	...	...	1 d		
...	6454·09	49·40	„	1548·97	...		
736·9	6449·27	50·56	„	1550·13	3 b	Ca.	
740·9	6438·35	53·19	„	1552·76	5 b	Ca, Cd.	
743·7	6431·73	54·79	„	1554·36	2 b		

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width	Origin, &c.	Groups.
744·3	6430·12	1555·18	0·43	1554·75	4 b	Fe.	
748·1	6420·63	57·48	„	1557·05	4 b	Fe.	Group 1560. Strong.
748·7	6419 17	57·83	„	1557·40	3 b		
750·1	6415·90	58·63	„	1558·20	1 a		
751·0	6414·10	59·06	„	1558·63	1 b		
752·3	6410·62	59·91	„	1559·48	4 b	Fe.	
753·8	6407·38	60·70	„	1560·27	3 b	Sr, Fe.	
756·9	6399·28	62·68	„	1562·25	5 b	Fe.	
759·3	6392·87	64·24	0·43	1563·81	3 b	Fe.	
764·2	6379·99	67·40	0·44	1566·90	1 a		
...	6377·58	67·99	„	1567·55	...		
...	6364·49	71·22	„	1570·78	...		
771·8	6361·41	71·98	„	1571·54	1 a	Zn.	
773·4	6357·92	71·84	„	1571·40	2 b	Fe.	
774·8	6354·28	73·74	„	1573·30	2 b	Fe.	
778·3	6346·34	75·71	„	1575 27	1 b	Ru, Ir.	
779·5	6343 40	76·44	„	1576·00	1 b		
781·9	6338·21	77·73	„	1577·29	3 b		
783·1	6336·16	78·24	„	1577·80	4 b	Fe.	
783·8	6334·54	78·65	„	1578·21	3 b	Fe.	
786·8	(6327·0)	80·5	„	1580·1	1 a		
788·9	6321·81	81·83	„	1581·39	3 b	Fe.	
791·0	6318·41	82·68	„	1582·24	1 d	Fe.	
791·4	6317·17	82·99	„	1582·55	3 b		
792·9	6314·18	83·74	„	1583·30	2 d	Fe.	
794·5	6309·78	84·84	„	1584·40	1 d		
798·1	6301 88	86·83	„	1586·	3 a		
798·5	6301·03	87·04	„	1586·60	4 a	Fe.	
799·8	6298·74	87·62	„	1587·18	2 b	Fe.	
800·3	6296·95	88·07	„	1587·63	2 b		
801·5	...	...	„	...	1 a		
801·2	6294·27	88·78	„	1588·34	1 a		
802·7	6291·78	89 38	„	1588·94	1 b		
803·5	6290·31	89·75	„	1589·31	2 a		
...	6286·69	90·66	„	1590·22	...		
805·8	6284·99	91·09	„	1590·65	1 b		
807·4	6281·81	91·89	„	1591·45	2 b		Group 1592. Strong.
808·2	6279·79	92·41	„	1591·97	2 c		

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width	Origin, &c.	Groups.
808·7	6278 47	1592·74	0·44	1592·30	1 c		
809·5	6277·09	93·09	"	1592·65	3 b	Au.	
809·9	6276·32	93·29	"	1592·85	2 d		
812·7	6270·16	94·86	"	1594·42	1 a		
813·1	6269·35	95·06	"	1594·62	2 a		
815·0	6264·31	96·34	"	1595·90	4 b	Fe.	Group 1597. Strong.
...	6262·68	96·76	"	1596·32	..		
816·8	6260 37	97·35	"	1596·91	2 b	Ti.	
818·0	6257·84	98·00	"	1597·56	3 c		
819·0	6255·51	98·59	"	1598·15	4 b	Fe.	
820·1	6253 40	99·13	"	1598·69	4 b	Fe.	
820·9	6251·76	1599·55	"	1599 11	4 b	Fe.	
823·5	6246·55	1600·88	"	1600·44	1 a	Fe.	
824·0	6245·62	01·12	0·44	1600 68	4 b	Fe.	
824·9	6243·49	01·67	0·45	1601·22	1 d	Two other rays of Kirchhoff's lie within this space, viz. 826·4 (2 a), and 827·6 (1 a).	
...	6242 60	01·90	"	1601·45	...		
...	6240 51	02·43	"	1601·98	...		
...	6239 42	02·71	"	1602·26	...		
...	6237 55	03·19	"	1602·74	...		
...	6237·09	03·31	"	1602·86	...		
828·0	6236·33	03·51	"	1603·06	2 a		
830·2	6231·72	04·69	"	1604·24	3 b	Fe.	Group 1604. Strong.
831·0	6229·91	05·16	"	1604·71	4 c	Fe.	
831·7	6228 35	05·56	"	1605·11	1 b		
...	6225·62	06·26	"	1605·81	...		
...	9222·57	07·05	"	1606·60	...		
...	6221·10	07·43	"	1606·98	...		
836·5	6218 46	08·11	"	1607·66	2 b	Ti.	
838·2	6215·67	08·83	"	1608·38	1 b		
838·6	6214·30	09·19	"	1608·74	2 b	Ti.	
839·2	6212·55	09·64	"	1609·19	2 b	Fe.	
845·7	6199·85	12·94	"	1612·49	2 b	Fe.	
849·7	6190·71	15·32	"	1614·87	3 c	Fe.	
851·2	(6188·3)	15·9	"	1615·4	1 a		
851·8	6187·26	16·22	"	1615·77	1 a		
8550	6179·46	18·26	"	1617·81	2 a	Fe.	

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups
856·8	6175·95	1619·19	0·45	1618·74	2 a	Ni.	
857·5	6174·51	19·56	„	1619·11	2 a		
858·3	6172·49	20·09	„	1619·64	2 a	Fe.	
859·7	6169 59	20·85	„	1620·40	3 a		Group 16 Strong.
860·2	6168 48	21·14	„	1620·69	3 d	Ca.	
861·6	6165 62	21·90	„	1621·45	2 a		
862·2	(6165·0)	22·1	„	1621·6	1 a		
863·2	6163·95	22·34	„	1621·89	2 c		
863·9	6162·69	22·67	„	1622·22	5 b		
864·4	6161·40	23·01	„	1622·56	1 d	Ca.	
...	6160·23	23·32	„	1622·87	...	Na.	
866 2	6156·90	24·19	„	1623·74	2 b	Identification of Ångstrom's ray with Kirchhoff's doubtful.	
867·1	(6155·3)	24·6	„	1624·1	2 b		
867·6	6154·41	24·85	„	1624·40	1 a	Na.	
...	6153·89	24·99	„	1624·54	...		
...	6153·33	25·14	„	1624·69	...		
869·2	6150·68	25·84	„	1625·39	2 b		
870·9	6148·28	26·47	„	1626·02	1 b	Fe.	
871·4	6146·76	26·82	„	1626·37	2 b		Group 16 Strong
872·5	6144·09	27·58	„	1627·13	1 b		
874·0	(6141·4)	28·3	„	1627·8	1 b		
874·3	6140·81	28·45	„	1628·00	4 b	Ba.	
...	6136·32	29·64	„	1629·19	...		
876·5	6136·82	29·51	„	1629·06	4 a		
877·0	6135·82	29·77	„	1629·32	4 c	Fe.	
879·8	6130·59	31·16	„	1630·71	1 b		
880·9	6128·61	31·69	„	1631·24	1 a		
881·6	6127·00	32·12	„	1631·67	2 a	Ti.	
882·6	6125·29	32·58	„	1632·13	1 a		
883·2	6123·92	32·94	„	1632·49	1 b		
884·9	6121·34	33·63	„	1633·18	4 b	Ca, Co.	
...	6118·93	34·27	„	1633·82	...		
887·7	6115·51	35·19	0·45	1634·74	2 a	Ni.	
890·2	6110·11	36·63	0·46	1636·17	1 b	Ba.	
891·7	6107·36	37·37	„	1636·91	2 a	Ni.	
...	6104·58	38·11	„	1637·65	...		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
894·9	6101·92	1638·83	0·46	1638·37	2 e	Ca, Li.	
896·1	6099·08	39·59	„	1639·13	1 a		
896·7	6097·66	39·97	„	1639·51	1 b	Ti.	
898·9	6095·20	40·63	„	1640·17	1 a		
899·1	6094·02	40·95	„	1640·49	1 a		
900·2	6092·42	41·38	„	1640·92	1 a	Identification on Kirchhoff's map doubtful.	
...	6090·59	41·88	„	1641·42	...	Ti.	
901·4	6088·42	42·46	„	1642·00	1 a	Identification on Kirchhoff's map doubtful.	
901·6	6086·69	42·93	„	1642·47	1 a		
902·4	(6085·1)	43·4	„	1642·9	1 a		
903·1	6083·27	43·85	„	1643 39	1 a	Ti.	
903·6	6082·10	44·17	„	1643·71	1 a		
904·6	(6080·4)	44·6	„	1644·1	1 a		
906·1	6077·80	45·33	„	1644·87	2 c	Fe.	
...	6075·87	45·85	„	1645·39	...		
912·1	6064·70	48·89	„	1648·43	3 b	Fe, Ti.	
916·3	6055·29	51·45	„	1650 99	2 b	Fe.	
...	6053·28	52·00	„	1651·54	...		
923·0	6041·37	55·25	„	1654·79	2 b		
929·5	6026·14	59·44	„	1658·98	2 b	Fe.	Group 1666. Strong.
931·3	6023·16	60·26	„	1659·80	4 b	Fe.	
932·5	6020·91	60·88	„	1660 42	4 b	Mn.	
933·3	6019·33	61·31	„	1660 85	4 c	Fe.	
935·1	6015 81	62·29	„	1661·83	4 b	Mn.	
936·7	6012 68	63·15	„	1662·69	4 b	Mn.	
937·4	6011·42	63·50	„	1663·04	1 b		
940·1	6007·65	64·54	„	1664.08	3 b	Fe.	
940·4	(6007·2)	64·7	„	1664·2	3 b	Ti ?	
943·4	6002·25	66·04	„	1665·58	3 b	Fe.	
946·6	5997·08	67·48	„	1667·02	3 b		
947·0	5996·44	67·66	„	1667·20	1 a		
949·4	(5995·6)	67·9	„	1667·4	1 b		
949·8	5990·20	69·39	„	1668·93	1 b		
...	5989·89	69·48	„	1669·02	...		
951·7	5988·10	69·98	„	1669·52	1 c		
952·9	5986·35	70·47	„	1670·01	3 b	Fe.	
954·3	5984·35	71·02	„	1670·56	3 b	Fe.	

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Grou
954·8	5983·01	1671·40	0·46	1670·94	3 b	Fe.	
...	5977·27	73·00	0·47	1672·53	...	Ti.	
958·8	5976·23	73·30	„	1672·83	3 b	Fe.	
959·6	5974·79	73·70	„	1673·23	3 b	Fe.	
961·9	5970·44	74·92	„	1674·45	1 a		
...	5969·22	75·26	„	1674·79	...		
963·7	5967·35	75·79	„	1675·32	1 c		
964·4	(5965·9)	76·2	„	1675·7	1 c		
...	5963·52	76·86	„	1676·39	...		
...	5961·67	77·38	„	1676·91	...		
968·7	5957·22	78·63	„	1678·16	2 a		
969·0	(5956·2)	78·9	„	1678·4	2 a		
969·6	5955·63	79·08	„	1678·61	3 a		
970·5	5953·90	79·57	„	1679·10	1 b		
971·5	5951·96	80·12	„	1679·65	2 c	Ti.	
972·1	5950·41	80·56	„	1680·09	1 b		
973·1	5948·44	81·11	„	1680·64	3 a		
973·5	5947·62	81·35	„	1680·88	3 a	Fe.	
974·3	5945·97	81·81	„	1681·34	2 a		
975·0	5944·98	82·09	„	1681·62	2 a		
...	5943·62	82·48	„	1682·01	...		
976·8	5941·71	83·02	„	1682·55	3 a		
977·4	(5940·9)	83·2	„	1682·7	2 a		
977·7	5940·43	83·38	„	1682·91	2 a		
979·1	5937·44	84·23	„	1683·76	1 b	Two other rays of Kirchhoff's lie in this interval, viz. 980·8 (1 a) and 981·2 (3 b).	
...	5935·05	84·91	„	1684·44	...		
...	5934·03	85·20	„	1684·73	...	Fe.	
982·0	5931·76	85·84	„	1685·37	1 a		
982·3	5931·18	86·00	„	1685·53	2 a		
983·0	5929·46	86·49	„	1686·02	3 c	Fe.	
984·5	5927·37	87·09	„	1686·62	1 c	Identification on Kirchhoff's map doubtful.	
986·3	5924·02	88·04	„	1687·57	1 a		
986·7	5922·99	88·34	„	1687·87	2 c		
987·4	5921·69	88·71	„	1688·24	1 b		
...	5920·87	88·94	„	1688·47	...		
988·9	5919·09	89·45	„	1688·98	2 a		
989·2	(5918·4)	89·6	„	1689·1	2 a		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
989·6	5917·51	1689·90	0·47	1689·43	2 a		
990·8	5914·60	90·73	„	1690·26	2 a		
991·2	(5914·1)	90·9	„	1690·4	1 a		
991·9	5913·30	91·10	„	1690·63	3 b	Fe.	
992·4	5912·09	91·45	„	1690·98	1 a		
993·9	5909·72	92·13	„	1691·66	1 b		
994·3	5908·13	92·58	„	1692·11	1 b		
995·0	5907·25	92·84	„	1692·37	1 a		
997·2	5904·56	93·61	„	1693·14	2 b	Fe.	
998·1	5902 77	94·12	„	1693·65	1 a		
998·9	5901·44	94·50	„	1694·03	1 a		
999·2	5900·52	94·76	„	1694·29	1 a		
1000·0	5899·10	95·17	„	1694·70	1 a	Ti.	
1000·4	5898·09	95·46	„	1694·99	1 a		
...	5897·40	95·66	„	1695·19	...		
1001·4	5897·08	95·75	„	1695·28	1 a		
...	5895·53	96·20	„	1695·73	...		
1002·8	5895·13	96·31	„	1695·84	6 b	D_1, Na.	Group 1697 (the D Group
...	5895 04	96·34	„	1695·87	...		
...	5892·50	97·07	„	1696·60	...		
1005·0	5892·10	97·19	„	1696·72	2 b	Ni.	
...	5891·56	97·34	„	1696·87	...		
...	5890·78	97·57	„	1697·10	...		
1006·8	5889·12	98 05	„	1697·58	6 b	D_2, Na.	
...	5886·69	98·75	„	1698·28	...		
...	5885·29	99·15	„	1698·68	...		
1011·2	5883 19	99·77	„	1699·30	3 a	Fe.	
...	5882 71	1699·90	„	1699·43	...		
...	5880·22	1700·62	„	1700·15	...		
...	5879·15	00·93	„	1700·46	...		
1023·0	5865·47	04·89	„	1704·42	1 a	Ti.	
...	5863·34	05·51	0·47	1705·04	...		
1025·5	5861·56	06·03	0·48	1705·55	3 a	Fe.	Group 1706 Strong.
1027·7	5858 68	06·87	„	1706·39	2 a	Fe.	
1029·3	5856·60	07·47	„	1706·99	3 c	Ni, Ca.	
...	5855·38	07·83	„	1707 35	...		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
...	5854·53	1708·08	0·48	1707·60	...		
1031·8	5852·84	08·57	,,	1708·09	2 a	Ba.	
1032·8	5851·48	08·97	,,	1708·49	1 a	Identification on Kirchhoff's map doubtful.	
1035·3	5847·50	10·13	,,	1709·65	1 a		
...	5846·41	10·45	,,	1709·97	...		
...	5832·63	14·49	,,	1714·01	...		
...	5821·85	17·67	,,	1717·19	...		
1058·0	5815·66	19·49	,,	1719·01	2 b	Fe.	Group 1719. Faint.
...	5813·28	20·20	,,	1719·72	...		
1063·0	5808·48	21·62	,,	1721·14	2 b	Fe.	Group 1722. Faint.
...	5807·30	21·97	,,	1721·49	...		
1065·0	5805·96	22·37	,,	1721·89	2 b		
1066·0	5804·57	22·78	,,	1722·30	1 a		
1067·0	5803·64	23·06	,,	1722·58	2 b	Fe.	
1070·5	5797·39	24·91	,,	1724·43	2 b	Fe.	Group 1725. Faint.
...	5796·52	25·17	,,	1724·69	...		
1073·5	5793·17	26·17	,,	1725·69	1 a		
1074·2	5792·40	26·40	,,	1725·92	1 a		
1075·5	5790·30	27·03	,,	1726·55	3 a	Fe.	
1077·5	5787·07	27·99	,,	1727·51	1 a	Identification of Ångström's ray with Kirchhoff's doubtful.	
1078·9 to 1079·7	5784·79	28·67	,,	1728·19	1		Group 1729. Faint.
1080·3	(5783·7)	29·0	,,	1728·5	1 a		
1080·9	5782·80	29·27	,,	1728·79	1 a		
1081·8	5781·39	29·69	,,	1729·21	2 b	Cu.	
1083·0	5779·94	30·12	,,	1729·64	2 a	Ba.	
...	5777·60	30·82	,,	1730·34	...		
1087·5	5774·21	31·84	,,	1731·36	2 a	Fe.	
1089·6	5771·33	32·70	,,	1732·22	2 a		
1096·1	5762·04	35·50	,,	1735·02	3 c	Fe.	Group 1737. Faint.
1096·8	(5761·3)	35·7	,,	1735·2	1 a		
1097·8	5760·30	36·02	,,	1735·54	1 a		
1100·4	5756·20	37·26	,,	1736·78	1 a		
1102·1	5753·66	38·02	,,	1737·54	3 b	Fe.	
1102·9	5752·27	38·44	,,	1737·96	3 a		

CATALOGUE (*continued*).

Kirchhoff.	Ång-ström.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
1103·3	5752·09	1738·50	0·48	**1738·02**	2 b		
1104·1	(5751·9)	38·6	„	**1738·1**	2 b		
1107·1	5746·88	40·07	0·48	**1739·59**	2 c		
1111·4	5741·02	41·85	0·49	**1741·36**	1 a		
1119·0	5730·64	45·01	„	**1744·52**	2 a	Fe.	
1122·6	5725·90	46·45	„	**1745·96**	2 a		
1128·3	5716·98	49·17	„	**1748·68**	2 b	Fe.	Group **1752**. Faint.
...	5716·26	49·39	„	**1748·90**	...		
1130·9	5714·09	50·06	„	**1749·57**	2 b	Fe, Ti.	
...	5713·43	50·26	„	**1749·77**	...		
1133·1	5710·94	51·02	„	**1750·53**	3 c	Fe.	
1133·9	5710 05	51·30	„	**1750·81**	3 c		
1135·1	5708·45	51·79	„	**1751·30**	4 d	Fe.	
1135·9	5707·28	52·15	„	**1751·66**	2 c		
1137·0	5706·14	52·50	„	**1752·01**	2 b		
1137·8	5705·16	52·80	„	**1752·31**	3 b	Fe.	
...	5703·59	53·28	„	**1752·79**	...		
...	5702·72	53·55	„	**1753·06**	...		
1141·3	5700·54	54·22	„	**1753·73**	2 c	Fe.	
1143·6	5697·38	55·19	„	**1754·70**	2 c		
...	5695·60	55·74	„	**1755·25**	...		
1146·2	5694·11	56·20	„	**1755·71**	1 b		
1147·2	5692·91	56·57	„	**1756·08**	1 b		
1148·6	5690·74	57·24	„	**1756·75**	1 b		Group **1758**. Strong.
1149·4	5689·48	57·63	„	**1757·14**	1 b	Ti.	
1151·1	5687·34	58·29	„	**1757·80**	4 b	Na.	
1152·5	5685·68	58·80	„	**1758·31**	2 b	Fe.	
1154·2	5683·61	59·44	„	**1758·95**	2 b		
(1155·7	5681·52	60·09	„	**1759·60**	3 b	Na.	
(1155·9	...	...	„	...	2 c	Ti.	
1158·3	5678·08	61·16	„	**1760·67**	2 a	Fe.	
1160·9	5674·58	62·24	„	**1761·75**	2 a	Ti.	
1165·2	(5668·6)	64·1	„	**1763·6**	1 a		
1165·7	(5667·9)	64·3	„	**1763·8**	1 a		
1167·0	5666·17	64·86	„	**1764·37**	1 d		Group **1767**. Strong.
1168·3	5664·67	65·33	„	**1764·84**	1 a		
1169·4	5662·95	65·86	„	**1765·37**	1 a		

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
1170·6	5661·65	1766·27	0·49	1765·78	2 c	Fe, Ti.	
...	5659·77	66·86	„	1766 37	...		
1174·2	5657·70	67·50	„	1767 01	5 d	Fe.	
1175·0	5656·85	67·77	„	1767·28	2 a		
1176 6	5654·56	68·48	„	1767 99	3 c	Fe.	
1177·0	(5654 0)	68·7	„	1768·2	2 a		
1177·3	5653·50	68·82	„	1768·33	1 a		
1177·6	(5653·1)	68·9	„	1768 4	1 a		
1178·6	5651·74	69·37	„	1768·88	1 a		
1179 0	(5651·2)	69·5	„	1769·0	1 a		
1179·4	(5650 7)	69·7	„	1769·2	1 a		
1179·8	(5650·0)	69·9	„	1769·4	1 a		
1180·2	5648·11	70·50	„	1770 01	1 a		
1183·4	5644·73	71·56	„	1771·07	2 a		
1184·8	5643 19	72·05	„	1771·56	3 a	Ti.	
1186·8	(5640·7)	72·8	„	1772·3	2 a		
1187·1	5640·35	72·94	„	1772·45	2 a	Fe.	
1189·3	5637·36	73 88	„	1773·39	3 b	Fe.	Group 1774. Faint.
1190·1	5636·39	74 18	„	1773·69	2 b		
...	5634·67	74·73	„	1774·24	...		
1193·1	5632·79	75·32	0·49	1774·83	3 a	Fe.	
1199·6	5624·50	77·93	0·50	1777·43	2 d		Group 1779. Strong.
1200·6	5623·36	78·30	„	1777·80	4 b	Fe.	
1201·0	(5622 8)	78·5	„	1778·0	2 a		
1203·5	(5621·1)	79·0	„	1778·5	2 c		
...	5619 41	79·55	„	1779 05	...		
1204·2	5618·63	79·79	„	1779·29	2 c		
1204·9	5617·95	80·01	„	1779·51	2 d		
1206·1	5616·22	80·56	„	1780·06	1 c		
1207·3	5614·65	81·05	„	1780·55	5 g	Fe.	
1217·8	5601·84	85·13	„	1784 63	5 d	Fe, Ca.	Group 1787 (the Calcium Group). Very strong.
1219·2	5600·35	85·60	„	1785·10	3 c	Ca.	
1220·1	5599·06	86·01	„	1785·51	2 c		
1221·6	5597·31	86·57	„	1786·07	5 d	Ca, Fe.	
1224·7	5593 56	87·77	„	1787·27	5 d	Ca.	
1225·3	5592·76	88·03	„	1787·53	1 b		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
1464·8	...	...	...	...	1 a		
1465·3	...	...	...	...	1 a		
1226·6	5591·32	1788·49	0·50	1787 99	2 d	Fe.	
1228·3	5589·17	89·17	„	1788·67	2 d	Ca.	
1229·6	5587·76	89·63	„	1789·13	4 c	Ca.	
1230·5	5586·79	89·94	„	1789·44	2 c		
1231·3	5585·69	90·29	„	1789 79	5 d	Fe.	
1232·8	5583·96	90·84	„	1790·34	2 b	Fe.	
1235·0	5580·94	91·81	„	1791·31	3 d	Ca.	Group 1795. Strong.
1237·8	5577·69	92·86	„	1792 36	2 c	Fe.	
1239·9	5575·04	93·71	„	1793·21	4 a	Fe.	
1242·6	5571·82	94·75	„	1794·25	6 c	Fe.	
1245·6	5568·64	95·77	„	1795·27	4 d	Fe.	
1247·4	5566·50	96·46	„	1795·96	3 b		
1248·6	5564·78	97·02	„	1796·52	3 d	Fe.	
1250·4	5562·88	97·63	„	1797·13	3 c		
1251·1	5561·92	97·94	„	1797·44	2 b		
1253·3	5559·40	98·76	„	1798·26	2 b		
1255·2	5557·22	1799·46	„	1798·96	2 b		
1257·5	5554·04	1800·49	„	1799 99	3 c		
1258·5	5552·79	00·90	„	1800·40	2 b		
1264·4	(5546·2)	03·0	„	1802·5	1 a		
1264·9	5545·59	03·23	„	1802 73	2 a	Fe.	
1267·3	5542·83	04·13	„	1803 63	3 a		
1268·0	5542·10	04·37	„	1803·87	3 a	Fe.	
1271·9	(5537·1)	06·0	„	1805·5	1 a		
1272·4	5536·48	06·20	„	1805·70	1 a		
1274·2	5534·21	06·94	„	1806·44	3 b	Ba.	
1274·7	(5533·6)	07·1	„	1806·6	3 a	Sr.	
1276·2	5531·77	07·74	„	1807·24	2 a	Fe.	
1276·7	(5531·2)	07·9	„	1807·4	1 a		
...	5529·64	08·44	„	1807·94	...		
1280·0	5527·54	09·12	„	1808·62	6 d	Mg.	Group 1809. Faint.
1281·3	5526·05	09·61	„	1809·11	3 c	Fe.	
1282·6	5524 81	10·02	„	1809·52	2 c		
...	5523·17	10·55	„	1810 04	...		
1285·3	5521·64	11·06	„	1810 55	2 c		

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
1287·5	5519·64	1811·71	0·50	1811·20	1 c	Ba.	
1289·7	5515·78	12·98	"	1812·47	2 c		
1291·9	5513·49	13·73	"	1813·22	3 c	Ti.	Group 1817. Faint.
1293·8	5511·95	14·24	"	1813·73	3 c	Ti.	
1294·5	5511·65	14·34	"	1813·83	3 c		
1295·6	(5510·3)	14·8	"	1814·3	1 a		
1296·3	5509·43	15·07	"	1814·56	2 c		
1297·5	5507·69	15·64	"	1815·13	1 a		
1298·9	5505·99	16·20	"	1815·69	5 c		
1299·7	5505·29	16·43	"	1815·92	2 c		
...	5502·90	17·22	"	1816·71	...	Ti.	
1302·0	5501·99	17·52	"	1817·01	2 c		
1303·5	5500·65	17·97	"	1817·46	5 c	Fe.	
1306·7	5496·74	19·26	"	1818·75	5 c	Fe.	
...	5493·62	20·29	"	1819·78	...		
...	5492·63	20·62	"	1820·11	...		
...	5489·05	21·81	"	1821·30	...	Fe, Ti.	
1315·0	5486·94	22·51	"	1822·00	4 c	Fe, Ti.	Group 1824. Faint.
1315·7	(5486·2)	22·8	"	1822·3	2 b		
1319·0	5482·51	23·98	0·50	1823·47	3 c	Co.	
1320·6	5480·29	24·72	0·51	1824·21	4 c	Sr, Ti.	
1321·1	(5479·7)	24·9	"	1824·4	3 b		
1323·3	5477·54	25·64	"	1825·13	2 b		
1324·0	(5476·8)	25·9	"	1825·4	2 b		
1324·8	5476·04	26·14	"	1825·63	4 d	Ni.	
1325·3	(5475·6)	26·3	"	1825·8	2 d		
1327·7	5473·43	27·01	"	1826·50	4 b	Ti.	
1328·7	5472·40	27·35	"	1826·84	2 b		
1330·4	5469·88	28·19	"	1827·68	3 b		
1333·3	(5466·6)	29·3	"	1828·8	1 a		
1334·0	5465·75	29·57	"	1829·06	4 b	Fe.	
1336·3	5463·33	30·39	"	1829·88	1 b		
1337·0	5462·44	30·68	"	1830·17	4 d	Fe.	
1337·8	(5461·5)	31·0	"	1830·5	1 b		
1338·5	(5460·7)	31·3	"	1830·8	1 b		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
1343·5	5454·84	1833·23	0·51	1832·72	6 c	Fe. } Between these rays is a ray of Ti.	
1351·1	5446·07	36·19	„	1835·68	5 d	Fe, Ti. }	Group 1839. Strong.
1352·7	5444·38	36·76	„	1836·25	5 b	Fe.	
1356·5	(5440·3)	38·1	„	1837·6	1 a		
1360·9	5435·58	39·73	„	1839·22	1 a		
1361·6	5434·99	39·93	„	1839·42	1 a		
1362·9	5433·17	40·55	„	1840·04	5 b	Fe.	
1364·3	5431·89	40·98	„	1840·47	1 a	These positions are on the assumption that what Ångström measured was the less refrangible of the two rays.	
1364·7	(5431·5)	41·1	„	1840·6	1 a		
1367·0	5428·96	41·97	„	1841·46	6 d	Fe, Ti.	
1371·4	(5424·8)	43·4	„	1842·9	1 b	Ba.	
1372·1	(5424·2)	43·6	„	1843·1	1 b		
1372·6	5423·70	43·76	„	1843·25	5 b	Fe.	
1374·8	5420·26	44·93	„	1844·42	1 c	Identification of Ångström's ray with Kirchhoff's doubtful.	
1375·8	5419·62	45·15	0·51	1844·64	2 a		
1377·4	5418·06	45·68	0·52	1845·16	1 a	Ti.	
1379·0	5416·22	46·31	„	1845·79	1 a		Group 1850. Strong.
1380·5	5414·63	46·85	„	1846·33	4 c	Fe.	
...	5413·54	47·22	„	1846·70	...		
...	5412·57	47·55	„	1847·03	...		
1384·7	5410·15	48·38	„	1847·86	4 c	Fe.	
1385·7	5409·12	48·73	„	1848·21	5 b	Cr. } Identification with Kirchhoff's very doubtful.	
1386·3	5408·73	48·86	„	1848·34	2 b	Ti. }	
1387·4	5406·67	49·57	„	1849·05	2 b		
1389·4	5404·95	50·16	„	1849·64	6 c	Fe.	
1390·9	5403·28	50·73	„	1850·21	5 d	Fe, Ti.	
1394·2	5399·71	51·95	„	1851·43	4 c	Fe.	
1395·3	5398·40	52·40	„	1851·88	1 c		
1396·4	5397·35	52·76	„	1852·24	2 c		
1397·5	5396·19	53·16	„	1852·64	5 c	Fe, Ti.	
1400·2	5393·63	54·04	„	1853·52	3 b		
1401·6	5392·38	54·47	„	1853·95	4 c	Fe.	
...	5391·38	54·81	„	1854·29	...		
1403·1	5390·73	55·04	„	1854·52	3 c		
1404·1	5389·60	55·42	„	1854·90	1 b	Fe.	

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
1405·2	5388·63	1855·76	0·52	1855·24	3 b		
1410·5	5382·47	57·88	,,	1857·36	4 c	Fe.	
1412·5	5380·34	58·62	,,	1858·10	2 b	Ti.	
1414·0	5378·76	59·16	,,	1858·64	2 b	Fe.	
1415·8	5376·70	59·88	,,	1859·36	2 b		
1419·4	5372·71	61·26	,,	1860·74	·2 b		Group 1863. Strong.
1421·5	5370·65	61·97	,,	1861·45	6 c	Fe.	
1423·0	5369·15	62·49	,,	1861·97	5 b	Fe.	
1423·5	(5368·6)	62·7	,,	1862·2	2 b	Co.	
1425·4	5366·65	63·36	,,	1862·84	5 b	Fe.	
1427·5	5364·53	64·10	,,	1863·58	3 b		
1428·2	5364·11	64·24	,,	1863·72	5 b	Fe.	
1430·1	5362·04	64·96	,,	1864·44	5 b	Fe.	
1431·2	5360·86	65·37	,,	1864·85	1 b		
1438·9	5352·57	68·26	,,	1867·74	4 c	Co, Fe.	Group 1870. Strong.
1440·2	5351·36	68·68	,,	1868·16	1 b	Co.	
1443·1	5348·75	69·59	,,	1869·07	2 b	Fe, Ca.	
1443·5	(5348·4)	69·7	,,	1869·2	2 b	Ca.	
1444·4	5347·51	70·03	,,	1869·51	4 b		
1445·7	5345·58	70·70	,,	1870·19	4 c		
..	5345·12	70·86	,,	1870·35	...		
1448·7	5342·75	71·69	,,	1871·18	2 a	Co.	
1449·4	5342·21	71·88	,,	1871·37	1 a	Co.	
1450·8	5340·38	72·53	,,	1872·01	5 c	Fe.	
1451·8	5339·35	72·89	,,	1872·37	5 b	Fe.	
1453·7	5337·75	73·45	,,	1872·93	1 a		
1454·7	5337·07	73·69	,,	1873·17	3 b	Ti.	
...	5336·03	74·05	,,	1873·53	...	Ti.	
1456·6	5333·96	74·78	,,	1874·26	1 a		
1458·6	5332·15	75·42	,,	1874·90	3 c	Fe.	
...	5330·68	75·93	,,	1875·41	...		
1461·5	5329·21	76·45	,,	1875·93	2 c		Group 1878. Strong.
1462·2	(5328·5)	76·7	,,	1876·2	2 c		
1462·8 } 1463·3 }	5327·42	77·08	,,	1876·56	{ 5 c { 5 c	Fe. Fe.	
1464·8	...	...	...	...	1 a		
1465·3	...	...	...	...	1 a		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
1466·8	5323·50	1878·46	0·52	1877·94	5 c	Fe.	
1468·8	5321·44	79·19	„	1878 67	2 b		
1469·6	5320 63	79·48	0·52	1878 96	1 b		
1473·9	5316·07	81·09	0·53	1880·56	5 b	Fe.	
1475·3	5314·54	81·63	„	1881·10	1 a		
1476·8	5313·15	82·12	„	1881·59	1 a		
1477·5	(5312·4)	82·4	„	1881·9	1 a		
...	5307·87	83·99	„	1883·46	...		
1483·0	5306·61	84·44	„	1883·91	4 b	Fe.	
...	5305·12	84·97	„	1884·44	. .		
...	5303 01	85·72	„	1885·19	...		
1487·7	5301·61	86 22	„	1885·69	5 b	Fe.	Group 1887. Faint.
1489·2	5300·10	86·76	„	1886·23	2 c		
1489·9	(5299·7)	86·9	„	1886·4	1 a		
1491·2	(5298 0)	87·5	„	1887·0	1 c		
1491·6	5297·63	87·64	„	1887·11	3 c		
1492·4	5296·70	87·97	„	1887·44	4 b		
1493·1	5296·21	88·14	„	1887·61	4 b		
1494·5	(5294 8)	88·6	„	1888·1	1 a		
1495·9	5292·71	89·39	„	1888·86	1 a		
1497·3	5291·82	89·71	„	1889·18	1 a	Cu.	
1501·3	5287 75	91·16	„	1890·63	2 b	Fe.	
...	5286·37	91·66	„	1891·13	...		
1504·8	(5284·3)	92·4	„	1891·9	1 a		
1505·3	(5283·8)	92·6	„	1892·1	1 a		
1505·7	(5283·4)	92·7	„	1892·2	2 a		
1506·3	5282·78	92·94	„	1892·41	5 c	Fe.	Group 1893. Strong.
1508·6	5281·06	93·56	„	1893 03	5 b	Fe.	
1510·3	5279·73	94·04	„	1893·51	2 c	Co.	
1515·5	5275·18	95·67	„	1895·14	4 d		Group 1898 (the E Group). Very strong.
1516·5	5274·41	95·95	„	1895·42	4 c		
1519·0	5272·66	96·58	„	1896·05	4 d	Fe.	
1522·7	5269·59	97·68	„	1897·15	6 c	E_1, Fe, Ca.	
1523·7	5268·67	98·01	„	1897·48	6 c	E_2, Fe.	
1525·0	5267·39	98·47	„	1897·94	1 b	Co.	
1527·7	5265·94	99·00	„	1898·47	5 c	Fe, Co.	

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
1528·7	5264·68	1899·45	0·53	1898·92	5 c	Ca.	
1530·2	5263·51	1899·87	"	1899·34	4 c	Ca.	
1531·2	5262·60	1900·20	"	1899·67	4 c	Fe.	
1532·5 } 1533·1 }	5261·11	00·74	"	1900·21	{ 4 b 4 b	Ca. Ca.	
...	5259·78	01·22	"	1900·69	...		
(1541·4	(5254·6)	03·1	"	1902 6	1 g		Group 1904. Faint.
(1541·9	5254·21	03·23	"	1902·70	3 b	Fe, Mn.	
1543·7	5252·60	03·82	"	1903·29	2 a	Fe.	
1545·5	5251 15	04·34	"	1903·81	2 a	Fe.	
1547·2	5249·81	04·83	0·53	1904·30	3 a	Fe.	
1547·7	5248·60	05·27	0·54	1904·73	2 a		
1551·0 } 1551·6 }	5246·43	06·06	"	1905·52	{ 2 a 2 a	Fe.	
1555·6	5242·86	07·36	"	1906·82	2 a	Fe.	
1557·3	5241·67	07·79	"	1907·25	3 a	Fe.	
1561·0	5239·16	08·70	"	1908·16	1 a	Fe.	
1564·2	5236·44	09·69	"	1909·15	1 a		
1566 5	5234·52	10·39	"	1909·85	2 b	Co.	Group 1912. Strong.
1567·5	5233·72	10·69	"	1910·15	2 b	Mn.	
1569 6	5232·24	11·23	"	1910·69	5 c	Fe.	
1573·5	5229 14	12·36	"	1911·82	5 a	Fe.	
1575·4	5227·63	12·91	"	1912·37	1 b		
(1577·2	5226·38	13·37	"	1912·83	5 c	Fe.	
(1577·6	(5226·0)	13·5	"	1913·0	3 c		
1579·4 } 1580·1 }	5224·42	14·09	"	1913·55	{ 2 a 2 a	Ti.	
1588·3	5217·28	16·71	"	1916·17	1 g	Cu.	Group 1917. Faint.
1589·1	5216·64	16·94	"	1916·40	3 b	Fe.	
1590·7	5215·64	17·31	"	1916·77	3 b	Fe.	
1592·3	5214·50	17·73	"	1917·19	3 b	Fe.	
1598·9	5209·59	19·54	"	1919·00	2 b	Ti.	Group 1921 (the Chromium Group). Strong.
(1601·4	5207·78	20·20	"	1919·66	6 b	Cr, Fe.	
(1601·7	(5207·6)	20·3	"	1919·8	3 d		
1604·4	5205·37	21·09	"	1920·55	5 b	Cr.	
1606·4	5203·88	21·64	"	1921·10	5 b	Cr, Fe.	

CATALOGUE (*continued*).

Kirchhoff.	Ång-ström.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
1609·2	5201·69	1922·45	0·54	1921·91	5 b	Fe.	
1611·3	5199·89	23·12	„	1922·58	1 c		
1613·9	5198·08	23·79	„	1923·25	3 b	Fe.	Group 1924. Faint.
1615·6	5197·19	24·12	„	1923·58	2 b	Identification on Kirchhoff's map doubtful.	
1616·6	...	...	...	...	1 b		
1617·4	...	...	...	...	2 b		
1618·2	...	...	...	...	3 b		
...	5195·33	24·81	„	1924·27	...	Mn.	
1618·9	5194·24	25·21	„	1924·67	4 b	Fe.	
1621·5	...	...	...	...	1 b		Group 1926. Strong.
1622·3	5191·80	26·11	„	1925·57	5 c	Fe.	
1623·4	5190·68	26·33	„	1925·99	5 b	Fe.	
1627·2	5188·33	27·40	„	1926·86	5 b	Ca.	
1628·2	5187·49	27·71	„	1927·17	1 b	Ti.	
1631·5	5185·24	28·55	„	1928·01	1 b	Fe.	Group 1932 (the great Magnesium Group).
1633·5	5183·10	29·35	„	1928·81	4 g		
1634·1	5182·75	29·48	„	1928·94	6 g	b_1, Mg.	
1634·7	(5182·3)	29·6	„	1929·1	4 g		
1638·7	5179·66	30·63	„	1930·09	1 b	Fe.	
...	5178·27	31·15	„	1930·61	...		
1642·1	5176·52	31·80	„	1931·26	1 b		
1643·0	5175·73	32·09	„	1931·55	1 b	Ni.	
1647·3	(5173·1)	33·1	„	1932·6	5 a		
1648·4	(5172·4)	33·3	„	1932·8	4 e		
1648·8	5172·16	33·43	„	1932·89	6 f	b_2, Mg. Winged ray.	
1649·2	(5171·9)	33·5	„	1933·0	4 e		
1650·3	5171·20	33·79	„	1933·25	6 b	Fe.	
1653·7	5168·48	34·80	„	1934·26	6 b	b_3, Fe, Ni.	
1654·0	(5168·2)	34·9	„	1934·4	4 c		
1655·6	5166·88	35·40	„	1934·86	6 e	b_4, Fe, Mg.	
1655·9	(5166·7)	35·5	„	1935·0	4 d		
1657·1	5165·88	35·78	„	1935·24	5 b	Fe.	
1658·3 to 1659·4	5164·73	36·21	„	1935·67	2 b	Fe.	
	...	...	...	...	1		
1662·8	5161·76	37·32	„	1936·78	5 b	Fe.	
1667·4	5157·64	38·49	„	1937·94	3 a	Fe.	
1670·3	(5156·0)	39·5	„	1939·0	1 a		

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
1671·5 1672·2	5155·20	1939·79	0·54	1939 25	3 b 4 a	Ni.	
1673·7	5153·22	40·53	"	1939 99	4 a		
1674·7	5152·69	40·73	"	1940·19	3 c	Cu.	
(1676·2	(5151·6)	41·1	"	1940·6	2 d		
1676·5)	5151·40	41·22	"	1940·68	4 b	Fe.	
1677·9	5150·28	41·64	"	1941·10	4 c	Fe.	
1681·6	5147·63	42·64	"	1942·10	4 c	Fe.	
1684·0	5145 87	43·30	"	1942·76	4 a	Ni, Fe.	
1684·4	...	...	"	...	1 b		
1685·9 1686·3	5144·64	43·77	"	1943·23	2 a 2 a		
1689·5 1690·0	5142·16	44·71	"	1944·17	5 c 5 b	Fe, Ni.	Group 1945. Strong.
1691·0	5141·37	45·01	"	1944·57	5 b	Fe.	
1693·8	5138·78	45·99	"	1945·45	6 e		
1696·5 1697·0	5136·93	46·69	"	1946·15	3 c 3 c	Fe, Ni.	
1701·8	5133·10	48·14	"	1947·60	5 c	Fe.	
(1704·6 1704·9)	5130·97	48·95	"	1948·41	2 c 3 b	Fe.	
(1707·6 1707·9)	5128 74	49·80	0·54	1949·26	2 c 3 b	Ti.	
1710·7	5126·81	50·53	0·55	1949·98	5 a	Fe.	
1712·2	5125·61	50·99	"	1950·44	3 b		
1713·4	5124·54	51·39	"	1950·84	5 b	Fe.	
1715·2	5123·32	51·86	"	1951·31	4 b	Fe.	
1717·9	5121·18	52·67	"	1952·12	4 b	Fe.	
1719·4	5120·08	53·09	"	1952·54	1 c	Ti.	
1726·9	(5115·3)	54·9	"	1954·4	1 a		
1727·3	5115·01	55·03	"	1954·48	3 b	Ni.	
...	5112·46	56·00	"	1955·45	...		
1733·6	5109·94	56·97	"	1956·42	5 b	Fe.	
1734·6	5108·98	57·34	"	1956·79	3 b		
1737·7	5107·16	58·03	"	1957·48	5 d	Fe.	
1741·0	5105·07	58·84	"	1958·29	4 b	Cu.	
1742·7 1743·1	5103·77	59·33	"	1958 79	1 a 1 a		
1744·6	5102·34	59·88	"	1959 33	2 a		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
1748·9	5099·19	1961·10	0·55	1960·55	3 c	Ni.	Group 1961. Strong.
1749·6	...	..	"	...	2 d	Ni.	
1750·4	5098·28	61·45	"	1960·90	5 c	Fe.	
1752·0	(5097·2)	61·9	"	1961·4	2 b		
1752·8	5096·64	62·08	"	1961·53	4 c	Fe.	
1762·0	5090·45	64·46	"	1963·91	3 c	Fe.	
1771·5	5083·68	67·08	"	1966·53	3 c		Group 1968. Faint.
1772·5	5082·60	67·50	"	1966·95	3 c	Fe.	
1774·0	5081·92	67·76	"	1967·21	2 b		
1775·8	5080 78	68·20	"	1967·65	3 b	Ni.	
1776·5	5079·88	68·55	"	1967·99	3 c	Ni.	
1777·5	5078 95	68·91	"	1968·36	3 c	Fe.	
1778·5	5078 01	69·27	"	1968·72	3 c	Fe.	
1782·7	5075·96	70·07	"	1969·52	3 b	Fe.	
1784·4	(5074·7)	70 6	"	1970·1	1 b		
1785·0	5074·24	70·74	"	1970·19	4 b	Fe.	
1787·7	(5072·5)	71·4	"	1970·9	2 c		
1788·7	5071·84	71·67	"	1971·12	3 b	Fe.	
1793·8	5068·27	73·06	"	1972·51	4 b	Fe.	Group 1973. Strong.
1795·4	(5067 0)	73·6	"	1973·1	1 a		
1796·0	5066·51	73·74	"	1973·19	3 a	Fe.	
1797·8	(5065·3)	74·2	"	1973·7	1 a		
1799·0	5064·53	74·52	"	1973·97	4 c	Ti.	
1799·6	...	...	"	..	3 b		
1806·4	5059·87	76·34	"	1975·79	2 b	Fe.	
1818·7	5051·11	79·76	"	1979·21	5 b	Fe.	Group 1980. Strong.
1821·4	5049·49	80·40	"	1979·85	5 b	Fe.	
1822·6	(5048·7)	80·7	"	1980·2	3 a		
1823·2	(5048·3)	80·9	"	1980·4	2 a		
1823·6	5047·92	81·01	"	1980·46	2 a	Fe.	
1828·6	(5044·6)	82·3	"	1981·8	1 b		
...	5043·54	82·73	"	1982·18	...	Fe. Possibly this ray is K 1828·6 or K 1830·1.	
1830·1	(5042·9)	83·0	"	1982·5	3 b		
1832·8	(5041·7)	83·5	"	1983·0	2 a	Ca.	

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
1833·4	5041·32	1983·61	0·55	1983·06	6 c	Fe, Ca. Ångstrom represents the Fe and Ca rays as coincident; Kirchhoff as separate but close.	Group 1984. Strong.
...	5040·80	83·81	"	1983·26	...		
1834·3	5040·28	84·02	"	1983·47	6 c	Fe.	
1835·9 1836·7 1837·5	5038·30	84·80	0·55	1984·25	3 c	Ti. Fe. Ti.	
1841·0 1841·6 1842·2	5035·47	85·91	0·56	1985·35	4 b	Ti. Ti. Ni.	
1848·9	5030·27	87·96	"	1987·40	2 c		
1851·0	5029·12	88·42	"	1987·86	1 c		
1853·2	5027·43	89·09	"	1988·53	3 b	Fe.	
1854·0	5026·54	89·44	"	1988·88	2 b	Fe.	
1854·9	5025·76	89·75	"	1989·19	4 c		
1856·9	(5024·5)	90·2	"	1989·6	1 c		
1857·9	(5023·9)	90·5	"	1989·9	2 b		
1860·4	(5022·4)	91·1	"	1990·5	2 b		
1861·3	5021·89	91·28	"	1990·72	3 c		
1862·3	5021·30	91·52	"	1990·96	2 b	Fe.	
1864·9	5019·52	92·22	"	1991·66	3 b	Ti.	
1867·1	5017·76	92·92	"	1992·36	5 d		Group 1993. Strong.
1868·4	(5016·7)	93·3	"	1992·8	5 b	Ni. This ray is represented on Ångstrom's map, but not inserted in his list.	
1869·5	(5016·2)	93·5	"	1992·9	1 c		
1870·6	(5015·4)	93·9	"	1993·3	3 a		
1872·4	5014·22	94·33	"	1993·77	5 b	Fe.	
1873·4	5013·48	94·62	"	1994·06	6 b	Ti.	
1874·2	(5013·0)	94·8	"	1994·2	2 a		
1874·8	(5012·6)	95·0	"	1994·4	2 a		
1875·8	(5012·0)	95·2	"	1994·6	2 c		
1876·5	5011·56	95·39	"	1994·83	6 b	Fe.	

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
1884·3	5006·72	1997·32	0·56	**1996·76**	6 b	Fe, Ti.	Group **1997**. Strong.
1885·8 1886·4	5005·14	97·95	„	**1997·39**	6 b 6 b	Fe. Fe.	
1889·5	5003·21	98·72	„	**1998·16**	1 g	Fe.	
1891·0	5002·11	99·16	„	**1998·60**	3 b	Fe.	
1892·5	5001·17	99·53	„	**1998·97**	5 b		
1893·8	(5000·4)	1999·8	„	**1999·2**	1 b		
1894·8	4999·86	2000·06	„	**1999·50**	3 b		
1896·2	4998·94	00·42	„	**1999·86**	4 b	Ti.	
1897·9	4997·54	00·98	„	**2000·42**	1 c		
1900·0	4996·05	01·58	„	**2001·02**	1 c		
1904·5	4993·42	02·63	„	**2002·07**	4 b	Fe.	
1905·1	(4993·2)	02·7	„	**2002·1**	2 c		
1908·5	4990·48	03·81	„	**2003·25**	5 d	Fe, Ti.	
1911·9	4988·46	04·63	„	**2004·07**	3 c	Fe.	
1916·2	(4985·8)	05·7	„	**2005·1**	1 d		
1917·5 1917·9	4984·84	06·08	„	**2005·52**	4 b 4 b	Fe. { Uncertain which of these rays belongs to Fe.	Group **2006**. Strong.
1919·8 1920·2	4983·45	06·64	„	**2006·08**	4 b 4 b	Fe, Ni. } (The less refrangible edge of a sodium [band.)	
1921·1	4982·73	06·93	„	**2006·37**	4 b	Fe.	
1922·0 1922·4	4981·96	07·24	„	**2006·68**	4 b 4 b	} (The more refrangible edge of a sodium band.)	
1923·5	4981·17	07·56	„	**2007·00**	4 b	Ti.	
1925·8	4979·76	08·13	„	**2007·57**	4 b	Ni.	
1928·0	4977·94	08·86	„	**2008·30**	4 b	Fe.	
1931·2	4975·89	09·69	„	**2009·13**	1 c		
1932·5	(4975·0)	10·1	„	**2009·5**	1 c		
1936·2	4972·43	11·09	„	**2010·53**	3 c	Fe.	
1939·5	(4970·3)	12·0	„	**2011·4**	3 c		
1940·6	(4969·6)	12·2	„	**2011·6**	2 c		
1941·5	(4969·0)	12·5	„	**2011·9**	3 b		
1943·5 1944·5	4967·44	13·11	„	**2012·55**	2 c 3 b	Fe. Fe.	
1947·6	4965·47	13·91	„	**2013·35**	4 c	Fe.	
1949·4	4964·78	14·19	„	**2013·63**	1 c		
1953·6	4961·50	15·40	„	**2014·84**	2 b	Fe.	

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
1960·8	4956·87	2017·40	0·56	2016·84	6 b		
					4	C.	
1961·2					6 b		
1964·3	(4954·0)	18·6	„	2018·0	2 c		
1966·2	4952·10	19·34	0·56	2018·78	2 b		
1966·7					2 b	Fe.	
1970·1	4949·54	20·39	0·57	2019·82	3 b	Fe.	
1974·7	4945·67	21·97	„	2021·40	4 b	Fe.	
1975·7	4944·69	22·37	„	2021·80	2 d		
1979·2	4941·97	23·48	„	2022·91	3 c	Fe.	
1982·8	4938·74	24·81	„	2024·24	5 a	Fe.	Group 2025. Strong.
1983·3					5 a	Fe.	
1983·8					5 a		
1984·5	4937·37	25·37	„	2024·80	4 b		
1985·8	4936·49	25·73	„	2025·16	4 b		
1986·9	(4935·7)	26·1	„	2025·5	2 a		
1987·5	4935·21	26·26	„	2025·69	3 a	Ni.	
1989·5	4933·55	26·94	„	2026·37	6 c	Ba.	
1990·4	4932·89	27·21	„	2026·64	5 b	Fe.	
1991·8	4931·31	27·86	„	2027·29	1 b		
1994·1	4929·61	28·56	„	2027·99	5 b	Fe.	
1996·9	4927·00	29·63	„	2029·06	2 a	Fe.	
1997·5					2 a		
1999·6	4924·64	30·61	„	2030·04	2 c		
2000·6	(4923·9)	30·9	„	2030·3	5 a		
2001·6	4923·20	31·20	„	2030·63	5 c	Fe.	Group 2032. Strong.
2003·2	4921·44	31·93	„	2031·36	3 b		
2003·7					1 a		
2004·9	(4920·1)	32·5	„	2031·9	2 d		
2005·2	4919·89	32·57	„	2032·00	6 d	Fe.	
2007·2	4918·31	33·22	„	2032·65	6 c	Fe.	
2008·1	4917·75	33·45	„	2032·88	1 b	Ni.	
2008·6	(4917·4)	33·6	„	2033·0	1 b		
2009·8	4916·57	33·94	„	2033·37	2 b		
2013·9	4913·35	35·27	„	2034·70	2 a		
2014·3					2 a		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
...	4911·32	2036·11	0·57	**2035·54**	...		
2015·7 to 2016·9	4911·1	36·2	„	**2035·6**	1		
(2017·7 2018·5)	(4909·3)	37·0	„	**2036·4**	2 b 1 2 b		
2019·5	(4908·5)	37·3	„	**2036·7**	2 a		
2021·2	4907·14	37·85	„	**2037·28**	1 g	Fe.	
2024·9	(4904·2)	39·1	„	**2038·5**	1 a		
2025·7	4904·08	39·12	„	**2038·55**	4 a	Ni.	
2026 8	4902·61	39·73	„	**2039·16**	4 b	Fe.	
2031·1	4899 47	41·04	„	**2040·47**	2 c	Ba.	
2035 4	4895·96	42 50	„	**2041·93**	1 b		
2039·6	4892 33	44·01	„	**2043·44**	1 b		Group **2046**. Strong.
2041·3	4890 98	44·58	„	**2044·01**	6 c	Fe.	
2042·2	4890 19	44·91	„	**2044·34**	6 b	Fe.	
2044·5 2045 0	4888 40	45·66	„	**2045·09**	5 b 5 b	Fe.	
2047 0	4886 81	46·32	„	**2045·75**	3 d	Fe.	
2047·8	4886 02	46·66	„	**2046·09**	3 b	Fe.	
2049·3 2049 7	4884·66	47·23	„	**2046·66**	3 a 3 a	Ti.	
2051·3	4883·30	47·80	„	**2047·23**	3 c		
...	4883 02	47·91	„	**2047·34**	...		
2053·0 2053·7	4881·12	48·71	„	**2048·14**	4 b 4 c	Fe.	
2058·0	4877·57	50·20	„	**2049·63**	6 c	Fe, Ca.	Group **2051**. Strong.
2060·0	4875·46	51·09	„	**2050·52**	2 b	Fe.	
2060·6	...	...	„	...	2 a		
2061·0	...	...	„	...	1 a		
2064·7	4873 08	52·09	„	**2051·52**	2 c	Ni.	
2066·2	4871 43	52·78	„	**2052·21**	5 c	Fe.	
2067·1	4870·61	53·13	„	**2052·56**	5 c	Fe.	
2067·8	(4870·1)	53·3	„	**2052·7**	3 b		
2068·8	(4869 4)	53·6	„	**2053·0**	3 b		
2070·6	(4868·1)	54·2	„	**2053·6**	1 b		
2071·3	4867·65	54·38	0·57	**2053·81**	1 b	Co.	
2073·5	4865·44	55·31	0·58	**2054·73**	3 b	Ni.	

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width	Origin, &c.	Groups.
2074·6	(4864·8)	2055·6	0·58	2055·0	2 b		
2076·5	4863·68	56·06	„	2055·48	1 b	Fe.	
2077·3	(4863·0)	56·3	„	2055·7	2 b		
2079·5 2080·0 2080·5	4860·74	57·31	„	56·73	4 e 6 g 4 e	F, H. Winged ray.	Group 2058 (the F Group). Strong.
2082·0	4859·29	57·91	„	2057·33	6 a	Fe.	
2084·6	(4856·7)	59·0	„	2058·4	2 b		
2086·0 to	(4855·3)	59·6	„	2059·0	1		
2086·9	4854·85	59·80	„	2059·22	3 b	Fe, Ni.	
2087·6	(4854·2)	60·1	„	2059·5	1 a		
2089·7	(4852·2)	60·9	„	2060·3	1 a		
2090·9	4851·02	61·42	„	2060·84	1 a		
2094·0	4848·23	62·61	„	2062·03	2 b	Ca.	
2096·8	...	...	...	...	1 b		
2098·8	...	...	...	...	1 a		
2099·8	4842·53	65·04	„	2064·46	2 a	Fe.	
2100·4	(4842·1)	65·2	„	2064·6	1 a		
2102·6	(4840·0)	66·1	„	2065·6	4 a		
2103·3	4839·29	66·42	„	2065·84	4 b	Co, Fe.	Group 2068. Faint.
2104·0	(4838·7)	66·7	„	2066·1	4 a		
2105·1	4837·80	67·05	„	2066·47	4 b		
2107·0	(4835·6)	68·0	„	2067·4	1 a		
2107·4	4835·19	68·17	„	2067·59	2 a	Fe.	
2109·1	4833·38	68·95	„	2068·37	2 b		
2111·1	4831·91	69·57	„	2068·99	3 b	Fe.	
2112·7	4830·34	70·25	„	2069·67	3 b	Ni.	
2115·0 2115·4	4828·57	71·01	„	2070·43	3 a 3 a	Ni.	
2119·8	(4824·2)	72·9	„	2072·3	1 b		
2121·2	4822·90	73·44	„	2072·86	4 b	Mn.	Group 2074. Faint.
2121·9	...	...	...	...	5 c		
2124·3	4819·91	74·73	„	2074·15	1 b		
2125·1	(4819·2)	75·0	„	2074·4	2 b		
2127·7	4817·07	75·95	„	2075·37	3 b		
2132·3	4811·70	78·27	„	2077·69	2 a	Ca.	Group 2081. Faint.
2132·7	...	...	„	...	1 a	Zn.	

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
2133·8 2134·3	4809·83	2079·08	0·58	2078·50	2 a 1 a	Ca.	
2136·0	4808·17	79·79	„	2079·21	5 a	Zn.	
2138·0	..	...	...	...	2 g		
2138·4	4806·49	80·52	„	2079·94	4 a		
2139·5	...	...	„	...	4 a		
2140·4	...	...	„	...	4 a		
2141·9	...	...	„	...	2 a		
2142·4	4804·54	81·36	„	2080·78	5 a	Ti.	
2144·6	4802·46	82·27	„	2081·69	4 a	Fe.	
2146·9 2147·4	4800·04	83·32	„	2082·74	3 a 4 a	Fe.	
2148·5 2148·9	4799·13	83·71	„	2083·13	4 a 3 a		
2150·1 2150·5	4797·70	84·33	...	2083·75	3 a 3 a	Fe.	
2157·0	...	...	„	..	3 a	Co.	Group 2088. Faint.
2157·4	4791·78	86·91	„	2086·33	5 a	Co.	
2159·0	(4790·3)	87·7	„	2087·1	1 c		
2160·6	4788·73	88·24	„	2087·66	5 a	Fe.	
2160·9	(4788·4)	88·4	„	2087·8	4 a		
2161·7	(4787·8)	88·6	„	2088·0	4 a		
2162·6	(4787·0)	89·0	„	2088·4	3 a		
2163·7 2164·0	4785·90	89·47	0·58	2088·89	4 a 4 a	Ni.	
2167·5	4782·73	90·86	0·59	2090·27	6 b	Mn.	
2171·5	4778·85	92·55	„	2091·96	3 b	Co.	
2172·2	(4778·3)	92·8	„	2092·2	2 a		
2175·7	4775·66	93·95	„	2093·36	2 b		
2176·4	(4775·0)	94·2	„	2093·6	1 b		
2179·9	4771·92	93·59	„	2093·00	5 b	Fe.	
2181·2	4770·37	96·27	„	2095·68	3 e		
2184·9	4767·59	97·49	„	2096·90	5 b	Fe.	Group 2100. Strong.
2186·5	4765·92	98·23	„	2097·64	3 b	Mn.	
2187·1 2187·9	4764·79	98·73	„	2098·14	5 a 5 a	Mn. The identity of either of these rays with Ångström's is doubtful.	
2188·5	(4764·5)	98·9	„	2098·3	5 a		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width	Origin, &c.	Groups.
2190·1	(4763·3)	2099·4	0·59	2098·8	5 b		
2191·9	(4762·0)	2100·0	,,	2099·4	3 e		
2192·3	4761·68	00·10	,,	2099·51	5 b	Mn. Winged ray.	
2193·3	4760·85	00·46	,,	2099·87	5 a	Mn.	
2195·7	(4758·6)	01·5	,,	2100·9	2 b		
2197·1 } 2197·7 }	4757·07	02·13	,,	2101·54	2 b 2 b	Ti.	
2198·8 } 2199·2 }	4755·34	02·90	,,	2102·31	4 a 3 a	Ni.	
2201·1	(4754·0)	03·5	,,	2102·9	2 b		
2201·9	4753·47	03·73	,,	2103·14	5 c	Mn.	
2203·3	(4752·5)	04·2	,,	2103·6	2 a		
2203·8	(4752·2)	04·3	,,	2103·7	1 a		
2205·1	4751·32	04·68	,,	2104·09	1 b		
2206·4	(4749·0)	05·7	,,	2105·1	1 a	Co.	
2206·7	(4748·8)	05·8	,,	2105·2	1 a		
2209·1	4747·34	06·44	,,	2105·85	4 c		
2211·7	4745·32	07·34	,,	2106·95	4 b	Fe.	
2213·4	4743·57	08·12	,,	2107·53	4 b		
2215·1	4741·89	08·86	,,	2108·27	1 b	Ti.	
2216·7	(4740·2)	09·6	,,	2109·0	3 b		
2217·5	(4739·5)	09·9	,,	2109·3	3 b		
2218·3	(4739·0)	10·2	,,	2109·6	3 a		
2219·8	(4737·5)	10·8	,,	2110·2	3 b		
2221·3	(4737·0)	11·0	,,	2110·4	1 a		
2221·7	(4736·6)	11·2	,,	2110·6	1 a		
2222·3	4736·24	11·38	,,	2110·79	5 c	Fe.	Group 2113. Faint.
2223·5	(4735·1)	11·9	,,	2111·3	3 c		
2225·4 } 2226·2 }	4733·07	12·79	,,	2112·20	2 b 4 b	Fe.	
2227·6	(4731·7)	13·5	,,	2112·9	2 a		
2228·6	(4731·0)	13·7	,,	2113·1	2 a		
2229·1	4730·95	13·74	,,	2113·15	4 b	Fe.	
2230·7	(4729·3)	14·5	,,	2113·9	4 a		
2231·2	(4729·0)	14·6	,,	2114·0	2 a		
2232·3	(4727·8)	15·1	,,	2114·5	4 a		
2233·7 2234·0	4726·70 . .	15·64 ...	,, ...	2115·05 . .	5 c 2 c	Fe. { Winged on more refrangible side.	

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
2237·4	4723·69	2116·99	0·59	2116·40	1 b		
2238·7	...	...	...	...	1 b		
2240·0	4721·53	17·96	„	2117·37	3 b	Zn.	
2241·4	(4720·5)	18·4	„	2117·8	2 b		
2245·1	(4717·1)	19·9	„	2119·3	3 b		
2246·2	(4716·1)	20·4	„	2119·8	1 b		
2248·2	4714·44	21·14	„	2120·55	3 c		Group 2124. Very strong.
2249·7	4713·81	21·43	„	2120·84	6 a	Ni. { Winged on more refrangible side.	
2250·0	...	...	...	...	3 d		
. .	4711·98	22·25	„	2121·66	...		
2255·4	4709·50	23·37	„	2122·78	4 b	Ti.	
2256·2	(4708·7)	23·7	„	2123·1	2 b		
2257·1	4708·37	23·88	„	2123·29	4 d	Fe.	
2257·6	(4707·8)	24·1	„	2123·5	2 b		
2258·5	(4707·0)	24·5	„	2123·9	2 c		
2259·4	4706·61	24·67	0·59	2124·08	4 c	Fe.	
2261·4	(4704·9)	25·4	0·60	2124·8	1 b		
2262·1	(4704·3)	25·7	„	2125·1	2 a		
2263·4	(4703·0)	26·3	„	2125·7	2 a	Mg.	
2264·3	4702·44	26·56	„	2125·96	6 d		
2266·2 } 2266·6 }	4700·95	27·23	„	2126·63	{ 2 a 2 a		
2268·0	4698·09	28·52	„	2127·92	3 a	Ti.	
2269·1	(4697·3)	28·9	„	2128·3	3 a		
2269·9	(4696·7) }	29·2	„	2128·6	{ 3 a		
2270·2	(4696·5) }				3 a		
2274·2	(4693·7)	30·5	„	2129·9	1 d		Group 2135. Faint.
2278·4	4690·69	31·88	„	2131·28	4 c	Fe, Ti.	
2279·8	...	...	...	...	2 a		
2280·7	...	...	...	...	2 a		
2282·0	. .	...	...	...	1 a		
2282·3	...	...	...	...	1 b		
2283·6	...	...	...	...	2 a		
2284·9	...	...	...	...	2 b		
2286·1	...	...	...	...	2 b		
2288·1	...	...	...	...	2 a		

CATALOGUE (*continued*).

Kirchhoff.	Ångström.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
(2289·1	...	...	...	..	1	Band.	
(2289·9	4681·37	2136·13	0·60	2135·53	2 b	Ti.	
2290·4	...	...	...	..	1 b		
2291·8	4679 65	36·91	„	2136·31	2 g	Zn.	
2293·1 to	...	...	„	..	2 a 1		
2293·6	4678 03	37·65	„	2137 05	3 b	Fe.	
2294·5	4676·91	38·16	„	2137·56	2 b	Cd.	
2301·7	4672 41	40·22	„	2139 62	4 c	Fe.	Group 2142. Strong.
2302·9	...	...	...	...	3 b		
2305·3	...	...	...	. .	3 d		
2306·8	...	...	...	...	4 c		
2307·8	...	...	...	...	1 b		
2308·2	4667·20	42·61	„	2142·01	5 b		
2309·0 to 2310·4	4666·45 ...	42·96 ...	„ ...	2142·36 ...	5 c 1	d. Ti. Winged ray.	
2310·9	...	..	...	...	2 e		
2312·5	4663·51	44·31	„	2143·71	3 b		
2313·7	...	...		...	3 b		
2314·3	4661·80	45·09	„	2145·49	3 b		
2316·0	...	...	„	...	2 b		
2316·6	...	...	„	..	1 b		
2322·0 } 2323·0	4656·15	47·70	„	2147·10	2 b / 2 b	Ti.	Group 2150. Strong.
2325·3	4654 07	48·66	„	2148 06	6 d	Fe, Cr.	
2328·3 } 2329·5	4651·25	49·96	„	2149·36	5 b / 5 b	Cu.	
(2332·8	..	...	„	...	2 b		
(2333·0	4647·99	51·47	„	2150·87	5 b		
2334·1	(4647·2)	51·8	„	2151·2	2 d	Ni.	
2335·0	(4646 6)	52·1	„	2151·5	5 b	Fe, Cr.	
2336·2	...	...	...	. .			
2336·8	4645·39	52·67	„	2152·07	5 b		
2339·9	4643·33	53·63	„	2153·03	4 b	Fe. {Between these rays a ray of Ti.	
2342·5	...	...	...	...	1 d		
(2343·7	4639·81	55·26	„	2154 66	1	{Identification with Kirchhoff's ray very doubtful	
(2345·1	4638·98	55·65	„	2155 05	2 d	Ti.	

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width	Origin, &c.	Groups.
2346·7	4637·30	2156·43	0·60	2155·83	4 b	Fe.	
2347·3					4 b	Fe.	
2349·4	(4635·9)	57·1	,,	2156·5	1 b		
2349·9	(4635·6)	57·2	,,	2156·6	2 b		
2351·4	4634·10	57·92	,,	2157·32	1 c		
2352·2					2 b		
2354·1	4632·18	58·81	,,	2158·21	6 c	Fe.	
2357·4	4629·77	59·93	0·60	2159·33	5 a	Between these a ray of Ti.	
2358·4					5 b		
2361·0	4627·32	61·08	0·61	2160·47	1 d		
2362·2	(4625·3)	62·0	,,	2161·4	1 c		
2362·6	4625·01	62·16	,,	2161·55	4 b		
2364·0					4 b	Fe.	
2365·9	(4622·7)	63·2	,,	2162·6	2 b		
2366·8	(4622·1)	63·5	,,	2162·9	1 b		
2367·7	4621·78	63·67	,,	2163·06	2 b		
2369·7	(4620·1)	64·5	,,	2163·9	2 b		
2371·4	(4618·8)	65·1	,,	2164·5	2 b		Group 2166. Strong.
2371·6	4618·71	65·11	,,	2164·50	4 b	Fe.	
2372·4	(4618·0)	65·4	,,	2164·8	4 b		
2374·2	4616·79	66·01	,,	2165·40	3 b	Ti.	
2375·0	(4615·9)	66·4	,,	2165·8	2 b		
2375·6	4615·56	66·58	,,	2165·97	4 b		
2376·1	(4615·3)	66·7	,,	2166·1	1 b		
2379·0	4612·78	67·89	,,	2167·28	6 c		
2381·6	4610·78	68·83	,,	2168·22	6 c	Fe.	
2386·1	4606·80	70·70	,,	2170·09	3 b	Ca.	Group 2172. Faint.
2386·6	...	...	...	...	2 a		
2388·7	...	...	...	...	2 c		
2389·7	4604·63	71·73	,,	2171·12	2 c	Identification with Kirchhoff's ray doubtful.	
2390·7	...	...	...	...	3 a		
2391·2	...	...	...	...	1 b		
2393·1	4602·77	72·60	,,	2171·99	5 b	Fe.	
2394·4	...	...	...	...	4 a		
2395·8	...	...	...	...	1 f		
2396·1	4600·62	73·62	,,	2173·01	3 b		

CATALOGUE (*continued*).

Kirchhoff.	Ång-ström.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
2396·7 to 2397·4	... ... 4599·61	... ... 2174·10	... ... 0·61	... ... 2173·49	2 a 1 2 a	Band.	
2399·6 2399·9	4597·36	75·16	,,	2174·55	3 a 3 a		
2402·2 2403·2	4595·00	76·28	,,	2175·67	3 b 3 b		
2404·9	(4593·7)	76·9	,,	2176·3	2 b		
2406·2	(4592·3)	77·6	,,	2177·0	2 b		
2406·6	4592·04	77·68	,,	2177·07	6 c	Fe.	Group 2180. Strong.
2407·2	(4591·6)	77·79	,,	2177·3	1 b		
2408·2	4590·91	78·22	,,	2177·61	4 b		
2409·0	(4590·3)	78·5	,,	2177·9	1 b		
2410·2	4589·48	78·90	,,	2178·29	4 b		
2412·8	(4587·8)	79·7	,,	2179·1	3 b		
2414·7	(4586·4)	80·4	,,	2179·8	2 b	Mg.	
2416·0	(4585·6)	80·7	,,	2180·1	3 d		
2416·3	4585·36	80·85	,,	2180·24	5 b	Fe, Ca.	
2418·0	(4584·4)	81·3	,,	2180·7	3 b		
2419·3	4583·35	81·81	,,	2181·20	5 b		
2420·6	(4582·3)	82·3	,,	2181·7	2 b		
2422·3	4580·93	82·96	,,	2182·35	6 d	Co, according to Kirchhoff, but according to Ångström it is a composite ray due to Fe, Ca.	
2423·8 2424·4	4579·65	83·57	,,	2182·96	3 c 4 b		
2426·5	4578·37	84·18	,,	2183·57	4 b	Fe, Ca.	
2428·4	(4577·2)	84·7	,,	2184·1	1 a		
2429·5	(4576·4)	85·1	,,	2184·5	3 b		
2431·9 2432·4	4573·66	86·43	,,	2185·82	2 b 1 b		
2435·3	(4571·7)	87·4	,,	2186·8	2 b	Ti.	Group 2189. Strong.
2435·5	4571·59	87·42	,,	2186·81	5 c		
2435·7	(4571·5)	87·5	,,	2186·9	2 b		
2436·5	4570·94	87·73	,,	2187·12	5 a		
2438·5	(4569·3)	88·5	,,	2187·9	1 a		
2439·4	4568·64	88·83	,,	2188·22	2 b		
2440·0	(4568·3)	89·0	,,	2188·4	1 a		
2441·8	4567·26	89·50	,,	2188·89	2 a		

CATALOGUE (*continued*).

Kirchhoff.	Ång-ström.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
2442·4	4566·71	2189·76	0·61	2189·15	1 a		
2443·9 } 2444·2 }	4564·93	90·61	„	2190·00	{ 5 a { 5 a		
2445·3	(4564·1)	91·0	„	2190·4	1 c		
2446·6	4563·30	91·40	„	2190·79	5 b	Ti.	
2452·1	4559·54	93·20	„	2192·59	2 c		
2454·1	4558·16	93·87	„	2193·26	4 b		
2457·5 } 2457·9 }	4555·42	95·19	0·61	2194·58	{ 4 b { 4 b	Ti. Fe.	Group 2196. Strong.
2458·6	(4555·0)	95·4	0·62	2194·8	3 a		
2459·5	(4554·5)	95·6	„	2195·0	2 b		
2460·4	(4554·0)	95·9	„	2195·3	1 c		
2461·2	4553·50	96·11	„	2195·49	6 b	Ba.	
2463·4	4551·84	96·91	„	2196·29	4 b	Ti.	
2466·0	4550·29	97·66	„	2197·04	3 a		
{ 2467·3	(4549·2)	98·2	„	2197·6	3 c	}	
{ 2467·6	4548·97	98·30	„	2197·68	5 c	e. Ti. } Winged ray.	
{ 2467·9	(4548·8)	98·4	„	2197·8	3 c	}	
2468·7	(4548·3)	98·6	„	2198·0	3 a		
2470·1	(4547·3)	99·1	„	2198·5	4 a		
{ 2471·2	4546·56	99·46	„	2198·84	2 b	Fe.	
{ 2471·4	(4546·3)	2199·6	„	2199·0	4 a		
2472·9 } 2473·8 } 2474·6 }	4543·98	2200·71	„	2200·09	{ 4 a { 2 c { 4 b	Ti.	
2475·5	(4542·1)	01·6	„	2201·0	1 c		
2477·4 } 2477·8 }	4541·84	01·75	„	2201·13	{ 2 a { 2 a		
2478·7	(4541·1)	02·1	„	2201·5	2 a		
2479·7 } 2480·1 }	4540·30	02·50	„	2201·88	{ 2 a { 2 a		
2481·1	...	...	...	...	1 a		
2482·1	(4538·1)	03·6	„	2203·0	1 a		
2482·4	4537·88	03·67	„	2203·05	1 c		
2486·6 } 2487·0 }	4535·59	04·78	„	2204·16	{ 5 b { 5 b	Ti. Ca.	Group 2210. Strong.
2488·2	(4534·4)	05·4	„	2204·8	4 b	Ca.	

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
2489·4	4533·31	2205·89	0·62	2205·27	5 d	Fe.	
2490·5, 2490·8	4532·13	06·47	,,	2205·85	5 a, 3 d	Ca. Ti.	
2493·0	(4530·7)	07·2	,,	2206·6	3 a		
2493·6	4530·32	07·35	,,	2206·73	5 a	Co. Winged ray.	
2493·9	...	...	,,	...	3 f		
2495·8	4528·83	08·07	,,	2207·45	5 b		
2497·2	4528·08	08·44	,,	2207·82	6 d	Fe.	
2499·0, 2499·8, 2500·3	4526·15	09·38	,,	2208·76	3 b, 3 b, 4 c	Ti.	
2502·2, 2502·4	4524·48	10·20	,,	2209·58	4 c, 1 b	Fe. } Ba.	
...	4523·02	10·91	,,	2210·29	...	A very faint ray.	
2505·6	4522·09	11·37	,,	2210·75	4 d	Ti.	
2509·4	4519·66	12·56	,,	2211·94	2 d		
2512·1, 2512·5, 2513·2, 2513·5	4517·90	13·42	,,	2212·80	1 e, 2 a, 2 b, 1 b	Ti.	
2517·0	(4514·2)	15·2	,,	2214·6	3 b		
2518·2	(4513·3)	15·7	,,	2215·1	2 c	Band.	
2518·4	(4513·2)	15·7	,,	2215·1	3 a		
2520·9	(4510·4)	17·1	,,	2216·5	3 a	The interpolated wave-lengths and oscillation-frequencies of these rays are very doubtful.	
2522·3	(4509·4)	17·6	,,	2217·0	1 a		
2525·0, 2525·4	4507·74	18·41	,,	2217·79	2 a, 1 b		
2527·0	(4506·6)	19·0	,,	2218·4	4 a		
2532·0	(4503·5)	20·5	,,	2219·9	2 b		
2535·5, 2535·9	4501·75	21·36	,,	2220·74	2 b, 2 b		Group 2223. Strong.
2536·6	4500·76	21·85	,,	2221·23	1 b		
2537·1	4500·31	22·07	,,	2221·45	5 c	Ti.	
2538·0, 2538·3	(4499·7)	22·4	,,	2221·8	1 b, 2 a		
2540·5	4498·27	23·08	,,	2222·46	2 g	Pt, Mn.	
2543·5	4496·22	24·09	,,	2223·47	4 c	Ti.	

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
2544·5	(4495·6)	2224·4	0·62	2223·8	2 d	Mn.	
2545·4	(4495 0)	24·7	,,	2224 1	1 c		
2547·2	4493·81	25·28	,,	2224·66	6 c	Fe.	
2547·7	(4493·5)	25·4	,,	2224·8	2 b		
2548·4	...	...	...	...	1 c		
2549·7	...	...	...	...	1 b		
2550·1	...	...	...	...	1 b		Group 2227. Faint.
2551·2	...	...	...	..	1 b		
2551·4	...	...	...	..	3 a	Possibly this may be the ray due to Mn instead of next.	
2552·4	(4491 0)	26·7	,,	2226 1	3 a	Mn.	
2552·6	...	..	...	. .	1 b		
2553·6	...	...	..	...	3 a		
2554·0	...	...	...	...	3 a		
2554·9	4489·49	27·42	,,	2226·80	3 a	Fe, Mn.	
2555·1	...	...	...	. .	2 c		
2556·3	...	...	...	...	2 c		
2559·9	4484·96	29·67	,,	2229·05	3 b	Fe.	Group 2230. Strong.
2562·1	4483·89	30·21	,,	2229·59	4 b	Fe.	
..	4483 09	30·60	0·62	2229·98	...		
2564·0 2565·0	4482·30	31·00	0·63	2230·37	3 b 6 c	 Fe.	
2565·9	(4481·3)	31·5	,,	2230·9	2 b		
2566·3	4481·00	31·64	,,	2231·01	3 d	Mg.	
2567·8 2568·4	4479·37	32·46	,,	2231·83	3 b 2 b	Fe. Mn.	
2574·4	4475·49	34·39	,,	2233 76	5 c	Fe.	Group 2235. Strong.
2579·3	4472·48	35·90	,,	2235·27	3 d	Mn.	
2581·0	(4471·5)	36·4	,,	2235·8	1 a		
2581·5	(4471·2)	36·5	,,	2235·9	1 a		
2582·0 2582·4	(4470·7)	36·8	,,	2236·2	2 a 2 a		
2582·8	(4470·4)	36·9	,,	2236·3	1 a		
2584·0 2585·4	4469 54	37·37	,,	2236·74	3 e 5 b	Fe. Ti. Doubtful whether Ångström's position is the mean of these.	
2587·9 2588·5	4466·05	39·11	,,	2238·48	3 a 5 b		
2589·7	(4465·2)	39·5	,,	2238·9	1 b		

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
2591·3	4464·09	2240·10	0·63	2239·47	4 a	Mn.	
2591·7	(4463·8)	40·2	,,	2239·6	2 c		
2593·0	(4463·0)	40·6	,,	2240·0	1 c		
2594·9	(4461·6)	41·3	,,	2240·7	2 b	Mn.	Group 2242. Strong.
2594·9 to 2595·4	...	...	...	..	1	Band.	
2595·4 } 2595·9	4461·23	41·53	,,	2240·90	{ 4 a, 4 a		
2595·9 to 2596·4	...	...	...	...	1	Band.	
2596·4	(4460·7)	41·8	,,	2241·2	2 c	Mn.	
2597·7	(4460·3)	42·0	,,	2241·4	3 b		
2598·5	(4459·5)	42·4	,,	2241·8	1 b		
(2599·4, 2599·7)	4458·72	42·80	,,	2242·17	{ 3 c, 5 b	Fe.	
2600·6, 2601·0, 2602·1	4457·83	43·24	,,	2242·61	{ 2 a, 2 c, 4 b	Mn, Ti.	
2602·9	...	...	...	...	1 a		
2603·6	...	...	...	...	2 b		
2604·0, 2604·8	4455·38	44·48	,,	2243·85	{ 1 a, 4 b	Mn. Double.	
(2605·8, 2606·6)	4454·16	45·09	,,	2249·46	{ 3 b, 2, 5 c	Mn. Ca.	
2607·1	(4453·6)	45·4	,,	2244·8	2 b		
2608·2	(4453·0)	45·7	,,	2245·1	3 c		
2608·6	(4452·8)	45·8	,,	2245·2	1 c		
2608·9	(4452·6)	45·9	,,	2245·3	1 a		
2610·2	(4451·8)	46·3	...	2245·7	1 a		
2612·3	4450·50	46·94	,,	2246·31	3 b	Mn.	
2613·6	(4449·8)	47·3	...	2246·7	2 c		
2614·1	4449·59	47·40	,,	2246·77	3 c	Ti.	
2616·5	(4448·6)	47·9	,,	2247	2 b		
2619·1, 2619·9, 2620·3	4447·07	48·67	,,	2248·04	{ 5 b, 3 a, 3 a	Fe. Ti.	
2622·3	...	...	...	...	1 b		Group 2250. Strong.
2624·1	...	...	...	...	1 b		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
2625·2					5 a	Ti.	
2625·9					4 a	Fe.	
2626·3	4442·40	2251·03	0·63	2250·40	2 a		
2627·0					5 b	Fe.	
2627·9	...	...	...	..	2 a		
2628·9	...	...	...	...	1 c		
2629·7	...	...	...	...	1 b		
2630·5	...	...	...	...	1 a		
2633·6	...	...	...	...	2 c		Group 2254. Faint.
2634·4	...	...	...	...	1 d		
2635·5	...	...	...	...	3 b		
2636·4	...	...	...	...	2 c		
2637·4	...	...	...	...	4 b		
2638·5	4434·65	54·97	„	2254·34	5 b	Ca. It is not certain which of this pair is the ray of Ca.	
2638·8					3 b		
2639·6	...	...	...	...	1 c		
2640·6	...	...	...	...	2 c		
2641·6	...	...	...	...	3 c		
2642·5	...	...	...	...	2 a		
2643·2	...	...	...	...	1 a		
2643·5	...	...	...	...	1 a		
...	4431 48	56·58	„	2255·95	...	Not shown in Ångström's map.	
2645·6	4429·97	57·35	„	2256·72	4 b	Fe.	
2646·2					2 g	La, Di (Kirchhoff).	
2650·5	4426·90	58·92	„	2258·29	5 b	Fe, Ti.	Group 2259. Strong.
2650·7					3 c		
2652·9	4425·07	59·85	„	2259·22	1 d	Ca.	
2653·2					5 b		
2656·7					1		
2657·9	4422·12	61·36	„	2260·73	3 b		
2658·6					1 b		
2664·9	4418·20	63·36	„	2262·73	3 a		Group 2264. Strong.
2665·9					3 b	Ti.	
2666·7	(4417·4)	63·8	...	2263·2	1 b		
2667·6	4416·69	64·14	...	2263·51	3 a		
2668·0					1 b		

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
2669·4	(4415·2)	2264·9	0·63	2264·3	3 b		
2670·0	4414·77	65·12	0·64	2264·48	6 e	Fe, Mn. Winged, chiefly on less refrangible side.	
2673·8	...	...	...	...	1 a		Group 2269. Strong.
2674·5	...	...	...	...	2 a		
2675·6	(4411·)	67·1	...	2266·5	2 c	Ti. Identification of Kirchhoff's ray with Ångstrom's doubtful.	
2676·5	...	...	...	...	2 a		
2677·2	...	...	...	...	1 a		
2678·4	...	...	...	...	1 a		
2679·0	(4408·6)	68·3	...	2267·7	2 a		
2680·0 / 2680·2	4407·80	68·70	...	2268·06	5 b / 3 b	Fe, Ca. / Ca.	
2681·2	(4407·0)	69·1	"	2268·5	5 a		
2683·1	(4405·9)	69·7	"	2269·1	4 b		
2686·0 / 2686·4 / 2686·8	4404·26	70·53	"	2269·89	3 c / 6 f / 3 e	Fe. Winged ray.	
2688·4	(4403·2)	71·1	"	2270·5	2 e		
2690·8 / 2691·1	4401·74	71·83	"	2271·19	5 b / 3 e	Fe, Ni.	
2692·3	4400·78	72·32	"	2271·68	3 c		
2693·5	4399·64	72·91	"	2272·27	4 c		
2695·2 / 2696·8	(4398·2)	73·7	"	2273·1	1	Band.	
2698·2	(4397·0)	74·3	"	2273·7	1 f		
2699·8 / 2700·7	(4395·8)	74·9	"	2274·3	1 / 2 a		
2702·1 / 2702·3 / 2702·5	4394·64	75·50	"	2274·86	3 b / 4 a / 3 b		
2703·5	(4393·7)	76·0	"	2275·4	3 a		
2703·8	4393·55	76·06	"	2275·42	1	Ti.	
to							
2704·9	4393·03	76·33	"	2275·69			
2707·4 / 2707·7	...	...	...	...	1 f / 3 a		
2708·9	...	...	...	...	4 b		
2709·6	...	...	...	...	2 b		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width	Origin, &c.	Groups.
2710·6 / 2710·9	4389·48	2278·17	0·64	2277·53	3 a / 1 g	Ca.	
2711·9	4388·53	78·67	„	2278·03	1 a	Fe.	
2712·8	...	...	...	...	2 a		
2713·3	...	...	...	...	3 a		
2714·3	4386·84	79·54	„	2278·90	2 a		
2715·2	...	...	...	...	2 b		
2716·1	...	...	...	...	1 d		
2718·5	4384·75	80·63	„	2279·99	3 g / 4 c	Ca. Winged ray. Wing very broad on less refrangible side.	Group 2281 Strong.
2719·0 to 2720·2	...	...	...	...	1		
2720·2 to 2720·8	...	. .	...	...	2	Fe.	
2720·8 to 2721·6	4382·82	81·64	„	2281·00	6		
2721·6 to 2722·8	...	. .	...	..	3		
	(4382·1)	82·0	„	2281·4			
2725·5	4380·49	82·85	„	2282·21	2 d		
2725·8	(4380·3)	82·9	„	2282·3	3 a		
2726·8	(4379·8)	83·2	„	2282·6	2 a		
2728·0	4379·16	83·54	„	2282·90	4 b	Ca, Fe.	
2728·4	...	...	...	...	1 b		
2729·8	...	...	...	...	2 c		
2730·7	...	...	...	...	1 b		
2731·6	4375·46	85·47	„	2284·83	...	Ca, Fe.	Group 2285 Faint.
2732·4	...	...	...	...	1 c		
2733·7	4374·22	86·12	„	2285·48	...		
2734·1 / 2735·7	...	...	...	...	3 b / 1 / 3 b		Group 2288 Faint.
2736·5	...	...	...	...	3 b		
2736·9	...	...	...	...	3 b		
2737·4	...	...	...	...	1 a		
2737·8	...	...	...	...	2 a		
2739·2	...	...	...	...	2 c		
2739·9	...	...	...	...	1 b		
2741·3	4370·60	88·01	„	2287·37	3 d		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
2741·7	(4370·4)	2288·1	0·64	2287 5	3 b		
2743·8	(4369 4)	88·6	„	2288·0	1 f	Cr, Fe. Winged ray.	
2744·1	4369·27	88·71	„	2288·07	4 c		
2744·3	(4369·2)	88·7	„	2288·1	1 d		
2746·8 to	(4368·2)	89·3	„	2288·7	1	Band.	
2747·2	(4368·0)	89·4	„	2288·8			
2747·6	(4367·8)	89·5	„	2288·9	3 a		
2748·0	4367·56	89 61	„	2288·97	4 c	Fe.	
2749·8	4366·39	90·22	„	2289·58	3 c		
2750·6	(4366·0)	90·4	„	2289·8	3 a		Group 2291. Faint.
2754·5	(4363 7)	91·6	„	2291·0	2 c		
2755·4	(4363 2)	91·9	„	2291·3	1 b		
2755·8	4362·97	92·02	„	2291·38	2 b		
2756·5	(4362·7)	92·2	„	2291·6	1 c	The interpolated wave-length and oscillation-frequency of this ray doubtful.	
2757·2	(4362 0)	92·5	„	2291 9	1 c		
2759·4	(4360·5)	93·3	„	2292·7	1 a		
2760·1	(4360·1)	93·5	„	2292·9	2 d		
2760·6	(4359 9)	93·6	„	2293·0	2 d		
2762·0	4359·10	94·05	„	2293·41	4 e	Cr.	
2763·8	4358·24	94·50	„	2293·86	3 f	Fe.	
2767·2	...	...	...	..	1 d	Identification of Kirchhoff's ray with Ångstrom's doubtful.	
2768·2	4355 72	95·83	„	2295·19	2 a		
2768·5	...	...	...	...	1 a		
2770·0	4354·56	96·44	„	2295·80	2 b		Group 2297. Strong.
2770·8	(4354·2)	96·6	„	2296·0	2 b	Fe.	
2774·0	4352·51	97·52	„	2296·88	5 c		
2775·4					4 c	Cr.	
2775·7	4351·86	97·87	„	2297·23	6 c		
2776·0					4 c		
2777·3 to	4350·86	98·40	„	2297·76	3 a	Wing on more refrangible side of this ray.	
2777·8	...	...	...	...	2		
to 2778·5	4350·4	2298·6	„	2298·0	1	Band.	
2781·2	...	...	„	...	2 b		
2782·2	...	...	„	...	1 b		
2782·9	...	...	„	...	3 b		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
2783·9	4346·74	2300·57	0·64	2299·93	1 b		
2784·8	(4346·3)	00·8	„	2300·2	1 c		
2785·1	(4346·1)	00·9	0·64	2300·3	2 c		
2788·8 / 2789·1	4344·44	01·79	0·65	2301·14	1 b / 3 c	Cr.	
2790·5	(4343·4)	02·3	„	2301·6	1 c		
2791·1	4343·10	02·50	„	2301·85	3 b	Fe.	
2793·0 to 2794·0	...	...	...	...	1		Group 2305 (the G′ group). Very strong.
2794·0 to 2795·7	...	..	...	...	2		
2795·7 to 2796·7	4340·10	04·09	„	2303·45	6	H. This hydrogen ray is sometimes called the ray G′.	
2796·7 to 2797·6	...	...	...	...	2		
2797·6	...	...	...	...	3 b		
to	(4339·5)	04·4	„	2303·7	2		
2798·0	...	...	...	...	3 b		
to	...	...	...	...	1		
2798·9	...	...	„	...	2 c		
to	(4338·2)	05·1	...	2304·4	1		
2799·5	...	...	...	...	2 c		
to	...	...	...	...	1		
2800·1	...	...	„	...	3 b		
to	(4337·3)	05·6	...	2304·9	1		
2800·7	...	...	„	...	3 b		
to	(4337·0)	05·7	„	2305·0	1		
2801·4	4336·80	05·85	„	2305·20	4 d	Cr.	
2804·5	4335·15	06·72	„	2306·07	1 b		
2805·4	4334·63	07·00	„	2306·35	1 b		
2806·9	...	...	...	...	1 c		
2807·2	...	...	...	...	2 a		
2808·6 / 2808·8 / 2809·0	4332·72	08·02	„	2307·37	1 b / 2 a / 1 b		

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
2810·8	...	...	...	...	2 b		
2811·7	...	...	...	...	2 a		
2812·0	...	...	...	...	2 a		
2812·5	...	...	...	...	2 a	Identification of Ångstrom's ray with Kirchhoff's very doubtful.	
2812·8	4330·10	2309·41	0·65	2308·76	1 e		
2814·1	...	...	...	...	1 b		
2817·7	...	...	...	...	3 c		
2819·2	...	...	...	...	3 b		
2819·6	...	...	...	...	2 b		
2820·6 to 2821·0	...	...	...	...	2		Group 2313. Very strong.
to 2821·6	...	...	...	...	3		
to 2822·3	4325·24	12·01	„	2311·36	6	Fe. Winged ray.	
to	...	...	...	..	3		
2823·4	...	...	...	...	4 c		
2824·2	...	...	...	...	3 a		
to	...	...	...	...	2		
2825·0	...	...	...	...	4 c		
to	...	...	...	...	3		
2825·9	...	...	...	...	4 b	It is uncertain whether K 2825·9 or K 2826·5 is the Titanium line measured by Ångstrom.	
to	...	...	...	...	3		
2826·5	4322·88	13·27	„	2312·62	4 e	Ti.	
2828·9	...	...	...	...	3 b		
2830·7	4320·33	14·64	„	2313·99	3 g	Ti.	
2834·2	4318·07	15·85	„	2315·20	5 c	Ca.	
2837·7	4316·69	16·59	„	2315·93	1 g		
2841·4	4314·62	17·70	„	2317·05	5 b	Fe.	Group 2321 (the G Group). Very strong.
2841·7					4 e		
2843·0	4313·76	18·16	„	2317·51	3 d	Ti.	
2843·3					4 a		
2844·0	...	...	...	...	3 b		
2845·3	4312·47	18·86	„	2318·21	4 f	Ti.	
to	...	...	...	...	2		
2846·1	4311·73	19·25	„	2318·60	3 c		
to	...	...	...	...	2		

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
2846·9	...	...	...	...	4 c		
to	...	...	...	...	1		
2847·7	...	...	...	...	4 a		
to	...	...	...	...	2		
2848·0	...	...	...	...	4 a		
to	...	...	...	...	2		
2848·4	...	...	...	...	3 b		
to	...	...	...	...	2		
2848·9	...	...	...	...	3 b		
to	...	...	...	...	2		
2849·3	...	...	...	...	3 b		
to	...	...	...	...	2		
2849·8	...	...	...	...	3 b		
to	...	...	...	...	2		
2850·2	...	...	...	...	3 b		
to	...	...	...	...	2		
2850·7	...	...	...	...	3 b		
to	...	...	...	...	2		
2851·1	..	...	...	...	3 b		
to	...	...	...	...	2		
2851·6	...	...	...	...	3 b		
to	...	...	..	...	2		
2852·0	...	...	...	...	4 a		
to	...	...	...	...	2		
2852·3	...	...	...	...	4 a		
to	...	...	...	...	1		
2853·1							
to	...	...	...	...	3		
2853·6							
to	...	...	...	...	4		
2854·1							
to	4307·25	2321·67	0·65	**2321·02**	6	**G.** Fe, Ti.	
2854·7							
to	...	...	...	...	4		
2855·2							
to	...	...	...	...	3		
2855·7							
2856·9	...	...	...	...	4 d		

CATALOGUE (*continued*).

Kirchhoff.	Ångström.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
2857·9							
to	...	...	...	...	3	Ti.	
2858·5	4305·30	2322·72	0·65	2322·07	4 a	Fe.	
to	...	...	...	...	2		
2858·9							
to	...	...	...	...	3		
2859·4							
to	...	...	...	...	1		
2860·2							
to	...	...	...	...	2		
2860·9							
to	...	...	...	...	1		
2861·7	...	...	...	...	4 b		
2861·9	...	...	...	...	3 b		
to	...	...	...	...	1		
2863·1	...	...	...	...	3 b		
2863·6							
to	...	...	...	...	4		
2864·2	...	...	...	...	5 b		
to	..	...	...	...	2		
2864·7	4301·95	24·53	„	2323·88	4 b	Fe, Ca.	
2865·3	...	...	...	...	4 c		
to	...	...	...	...	1		
2866·3	4300·66	25·22	„	2324·57	5 b	Ca.	
to	...	...	...	...	3		
2867·1							
to	...	...	...	...	2		
2868·1	...	...	...	...	4 c		
2869·7	4298·56	26·36	„	2325·71	5 c	Fe, Ca.	
to	...	...	...	...	4		
2871·2							
2872·2	4297·65	26·85	„	2326·20	4 d		
...	4296·77	27·33	„	2326·68	...	Fe. Kirchhoff records five other rays in this region, viz. 2873·4 (2 b), 2873·9 (2 b), 2874·3 (3 b), 2874·7 (2 b), and 2875·2 (4 c), on a background of intensity 1.	
...	4295·03	28·27	„	2327·62	3 b	Ti.	
...	4293·96	28·85	„	2328·20	5 c	Fe, Ti.	Group 2331. Faint.
...	4292·08	29·87	„	2329·22	3 b		
...	4290·70	30·62	„	2329·97	3 c	Ti.	
...	4289·44	31·31	„	2330·66	3 b	Ca, Cr.	
...	4288·78	31·67	„	2331·02	2 a		
...	4287·47	32·38	„	2331·73	4 a	Fe, Ti.	

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width.	Origin, &c.	Groups.
...	4283 98	2334·28	0·65	**2333·63**	1 b		
...	4282·23	35·23	0·65	**2334·58**	...	Ca. / Fe. } Probably the mean of a pair.	Group **2335**. Faint.
...	4280·51	36·17	0·66	**2335·51**	1 a	Mn.	
...	4279·67	36·63	"	**2335·97**	{ 1 a / 3 b	} Mean of a pair.	
...	4276·96	38·11	"	**2337·45**	1 b		Group **2340**. Faint.
...	4274·63	39·38	"	**2338·72**	6 e	Ca, Cr.	
...	4273·05	40·25	"	**2339·59**	1 b	Ti.	
...	4271·33	41·19	"	**2340·53**	{ 6 f / 6 e	Fe, Ca. / Fe. { Double ray. Each component wing-ed on both sides.	
...	4269·51	42·19	"	**2341·53**	4 a		
...	4267 75	43·15	"	**2342·49**	5 a	Fe. Triple ray.	
...	4263·97	45·23	"	**2344·57**	{ 2 a / 2 a	Fe. / Fe. } Double ray.	
...	4261·42	46·64	"	**2345·98**	1 a		Group **2347**. Faint.
...	4260·02	47·41	"	**2346·75**	6 e	Fe.	
...	4258·43	48·28	"	**2347·62**	2 a	Mn.	
...	4255·38	49·97	"	**2349·31**	1 a	Fe.	Group **2350**. Faint.
...	4253 90	50·78	"	**2350·12**	6 d	Fe, Cr.	
...	4252·45	51·58	"	**2350·92**	1 g		
...	4250·54	52·64	"	**2351·98**	5 d	Fe.	
...	4249 81	53·05	"	**2352·39**	4 d	Fe, Ca.	
...	4248 16	53·96	"	**2353·30**	3 b		
...	4246·89	54·66	"	**2354·00**	5 c	Fe, Ca.	
...	4245·20	55·60	"	**2354 94**	5 c	Fe.	
...	4243·12	56·76	"	**2356·10**	5 d		
...	4241·92	57·42	"	**2356·76**	4 d		
...	4238·75	59·19	"	**2358·53**	5 c	Fe. { Between these two other rays, Fe and Fe, Ca.	Group **2359**. Strong.
...	4236·66	60·35	"	**2359·69**	3 d	Ti.	
...	4235·56	60·96	"	**2360·30**	{ 6 c on 4 g	} Fe.	

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width	Origin, &c.	Groups.
...	4233 00	2362·39	0·66	2361·37	6 b	Fe, Ca.	Group 2363. Faint.
...	4229 16	64·53	„	2363·87	5 b	Fe.	
...	4226·36	66 10	„	2365·44	6 a on 4 g	g. Ca. Winged on both sides. Very strong.	Group 2367. Strong.
...	4224 22	67·30	„	2366·64	1 a	Not in Ångstrom's map.	
...	4222 88	68·05	„	2367·39	2 b	Not in Ångstrom's map.	
...	4221 71	68·71	„	2368·05	5 d	Fe.	
...	4218 34	70·60	0·66	2369·94	5 d	Fe.	Group 2371. Faint.
...	4216·58	71·59	0·67	2370 92	3 b	Between these a ray of Fe.	
...	4215 33	72·29	„	2371·62	6 e	Ca.	
...	4213·43	73·36	„	2372·69	2 a	Fe.	
...	4209·90	75·35	„	2374 68	5 c	Fe. Between these two other rays of Fe.	
...	4206·25	77·41	„	2376·74	4 b	Fe. Between these a ray of Fe.	
...	4204 55	78·37	„	2377·70	4 b	Fe.	
...	4203·29	79 09	„	2378·42	1 a	Fe.	Group 2380. Strong
...	4201 56	80 07	„	2379·40	6 b on 2 g	Fe. Winged ray.	
...	4200 27	80·80	„	2380·13	4 g	Fe.	
...	4198·13	82·01	„	2381 34	5 a	Fe.	
...	4197·98	82·10	„	2381 43	4 a 6 d	Fe. Double and nebulous.	
...	4196·52	82·93	„	2382.26	1 a	Between these a ray of Fe.	
...	4195·42	83·55	„	2382·88	2 a	Fe.	
..	4194·73	83·94	„	2383·27	4 a	Between these a ray of Ca.	
...	4191·17	85·97	„	2385·30	6 a on 4 f	Fe.	Group 2387. Strong.
...	4188·48	87·50	„	2386·83	3 a 3 a	Ca. Double ray.	

Catalogue (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width	Origin, &c.	Groups.
...	4187·18	2388·24	0·67	**2387·57**	5 f	Fe. } Double winged ray.	
...	4186·68	88·53	"	**2387·86**	5 d	Fe.	
						} Between these a ray of Fe, Ti.	
...	4183 53	90·33	"	**2389 66**	2 b		Group **2392**. Faint.
...	4181·35	91·57	"	**2390 90**	{ 2 a 5 f	Fe.	
...	4178·85	93·00	"	**2392 33**	4 e		
...	4177·10	94·00	"	**2393·33**	5 e	{ Fe. The least refrangible of a group of four rays of Fe.	Group **2395**. Faint.
...	4171·77	2397·06	"	**2396·39**	{ 4 4 e 3 g	Fe. Fe Fe, Ti.	
						} Between these a ray of Fe.	
...	4166 64	2400·01	"	**2399 34**	5 e	Fe.	
...	4164·95	00·99	"	**2400·32**	3 c		
...	4163·14	02·03	"	**2401·36**	4 c	Ti.	
...	4160 87	03·34	"	**2402·67**	{ 3 b 3 b	} Double, nebulous.	
...	4158·52	04·70	"	**2404·03**	{ 4 c 4 b	Fe.	
...	4157·43	05·33	0 67	**2404·66**	5 d	Fe.	
...	4155·74	06·31	0·68	**2405·63**	{ 6 d 4 c	Fe.	
...	4153·79	07·44	"	**2406·76**	{ 4 b 4 b 5 c	Fe. Fe. Fe.	
...	4151·53	08·75	"	**2408·07**	6 c	Fe.	
...	4150·36	09·43	"	**2408·75**	4 d	Fe.	
...	4148·60	10·45	"	**2409·77**	4 c	Fe.	
...	4147·10	11·32	"	**2410·64**	2 b	Fe.	
...	4143·14	13·63	"	**2412·95**	{ 6 f 5 c	Fe. } Double. Winged externally. Fe.	Group **2413**. Faint.
...	4141·73	14·45	"	**2413·77**	{ 1 b 1 a		
...	4139 26	15·89	"	**2415·21**	{ 1 a 1 a		

CATALOGUE (*continued*).

Kirchhoff.	Ångstrom.	Reciprocals.	Reduction to vacuum.	Frequency.	Intensity and width.	Origin, &c.	Groups.
...	4136·36	2417·58	0·68	2416·90	{2 a 1 a		
...	4133·94	19·00	„	2418·32	{4 b 4 b	} Fe. Winged double ray.	Group 2419. Strong.
...	4131·52	20·42	„	2419·74	6 e	Fe, Ca. } Between these two rays of Fe. Winged ray.	
...	4127·27	22·91	„	2422·23	{3 a 4 c	Fe.	
...	4125·66	23·85	„	2423·17	{2 a 2 a		
...	4122·83	25·52	„	2424·84	3 a	Fe.	
...	4121·53	26·28	„	2425·60	4 b	Fe.	
...	4120·57	26·85	„	2426·17	4 b	Fe.	
...	4118·72	27·94	„	2427·26	2 b		
...	4117·78	28·49	„	2427·81	{6 a 5 a	} Fe. Closely double ray. Both *may* be Fe.	
...	4101·20	38·31	„	2437·63	{6 b on 4 g	} **h.** H. Winged on both sides.	Group 2439 (the *h* group). Very strong.
...	4097·55	40·48	0·68	2439·80	3 b	Ca, Fe.	
...	4095·64	41·62	0·69	2440·93	3 b	Ca.	
...	4094·59	42·25	„	2441·56	4 d		
...	4091·87	43·87	„	2443·18	5 g	Ca.	
...	4089·81	45·10	„	2444·41	2 a		
...	4084·17	48·48	„	2447·79	4 c	Fe. } Between these two rays of Mn.	Group 2448. Faint.
...	4079·68	51·17	„	2450·48	4 f	Mn.	Group 2453. Strong.
...	4077·05	52·75	„	2452·05	4 f	{ Ca. Winged, especially on less refrangible side.	
...	4076·35	53·17	„	2452·48	{3 a 3 a	} Fe. Closely double.	
...	4071·00	56·40	„	2455·71	6 g	Fe. Winged on both sides.	Group 2458. Strong.
...	4066·33	59·22	„	2458·53	{2 a 2 a	} Fe.	
...	4062·90	61·30	„	2460·61	6 g	} Fe, Mn. Winged on both sides.	

CATALOGUE (*continued*).

Kirchhoff.	Ång-strom.	Reci-procals.	Reduc-tion to va-cuum.	Frequency.	Inten-sity and width	Origin, &c.	Groups.
...	4057·22	2464·74	0·69	**2464** 05	6 a		Group **2466**. Faint.
...	4054·48	66·41	0·69	**2465** 72	5 a	Fe, Mn.	
...	4051·75	68·07	0·70	**2467** 37·	2 a	Fe.	
...	4048·22	70 22	,,	**2469**·52	5 b	Mn.	
...	4045·10	72·13	,,	**2471**·43	6 g	Fe. Winged on both sides.	Group **2473**. Strong.
...	4040·13	75·17	,,	**2474**·47	{ 6 c / 3 a	Mn. / Fe. } Triple.	
...	4033·92	78·98	,,	**2478**·28	6 c	Mn. } Between these two rays of Mn and one of Fe.	Group **2480**. Strong.
...	4029·50	81·70	,,	**2481** 00	6 c	Mn. } Wing on more refrangible side.	
...	4024·43	84·82	,,	**2484**·12	4 b	Fe.	
...	4020·27	87·39	,,	**2486**·69	5 c	Fe.	
...	4016·78	89·56	,,	**2488**·86	4 c	Fe. Close double ray.	
...	4004 90	96·94	,,	**2496**·24	6 g	{ Fe. Winged, especially on less refrangible side.	Group **2498**. Strong.
...	4001·55	2499·03	,	**2498**·33	3 b	Fe.	
...	3997 98	2501·36	0·70	**2500**·66	4 g	Fe.	
...	3968 10	20·10	0·71	**2519**·39	6	$\mathbf{H}_1$, Fe, Ca. } Very strong nebulous wings on both sides of each of these rays. Many rays between them, especially two rays of Al, both winged.	Group **2530** (the great H Group). Very strong.
...	3933·00	42·59	,,	**2541**·88	6	$\mathbf{H}_2$, Fe, Ca.	

Report of the Committee, consisting of Professor CAYLEY, Dr. FARR, Mr. J. W. L. GLAISHER, Dr. POLE, Professor FULLER, Professor A. B. W. KENNEDY, Professor CLIFFORD, *and* Mr. C. W. MERRIFIELD, *appointed to consider the advisability and to estimate the expense of constructing* Mr. BABBAGE'S *Analytical Machine, and of printing Tables by its means. Drawn up by* Mr. MERRIFIELD.

WE desire in the first place to record our obligations to General Henry Babbage for the frank and liberal manner in which he has assisted the Committee, not only by placing at their disposal all the information within his reach, but by exhibiting and explaining to them, at no small loss of time and sacrifice of personal convenience, the machinery and papers left by his father, the late Mr. Babbage. Without the valuable aid thus kindly rendered to them by General Babbage it would have been simply impossible for the Committee to have come to any definite conclusions, or to present any useful report.

We refer to the chapter in Mr. Babbage's 'Passages from the Life of a Philosopher,' and to General Menabrea's paper, translated and annotated by Lady Lovelace, in the third volume of Taylor's 'Scientific Memoirs,' for a general description of the Analytical Engine.

I. *The General Principles of Calculating Engines.*

The application of arithmetic to calculating machines differs from ordinary clockwork, and from geometrical construction, in that it is essentially discontinuous. In common clockwork, if two wheels are geared together so as to have a velocity ratio of 10 to 1 (say), when the faster wheel moves through the space of one tooth, the angular space moved through by the slower wheels is one-tenth of a tooth. Now in a calculating machine, which is to work with actual figures and to print them, this is exactly what we *don't* want. We require the second wheel not to move at all until it has to make a complete step, and then we require that step to be taken all at once. The time can be very easily read from the hands of a clock, and so can the gas consumption from an ordinary counter; but a moment's reflection will show what a mess any such machinery would make of an attempt at printing.

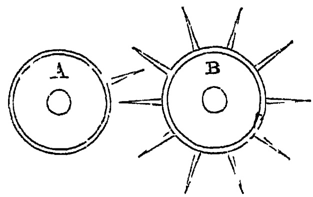
This necessity of jumping discontinuously from one figure to another is the fundamental distinction between calculating and numbering machines on the one hand, and millwork or clockwork on the other. A parallel distinction is found in pure mathematics, between the theory of numbers on the one hand, and the doctrine of continuous variation, of which the Differential Calculus is the type, on the other. A calculating machine may exist in either case. The common slide-rule is, in fact, a very powerful calculating machine in which the continuous process is used, and the planimeter is another.

Geometrical construction, being essentially continuous, would be quite out of place in the calculating machine which has to print its results. Linkwork also, for the same reason, is out of place as an auxiliary in any form to the calculation. It may be of service in simplifying the construction of the machine; but it must not enter into the work as an equivalent for arithmetical computation.

The primary movement of calculating engines is the *discontinuous train*, of which one form is sketched in the accompanying diagram (fig. 1):—B is the follower, an ordinary spur wheel with (say) 10 teeth; A is its driver, and this has only a single tooth. With a suitable proportion of parts, the single tooth of A only moves B one interval for a whole revolution of A; for it only gears with B by means of this single tooth. When that is not in gear, A simply slips past the teeth of B without moving the latter.

All the other machinery of calculating engines leads up to and makes use of this, or of some transformation of it, as its means of dealing with units of whatever decimal rank, instead of allowing indefinite fractions of units to appear in the result which has to be printed from.

FIG. 1.



The primary operation of calculation is counting: the secondary operation is addition, with its counterpart, subtraction. The addition and subtraction are in reality effected by means of counting, which still remains the primary operation; but the necessity for economising labour and time forces upon us devices for performing the counting processes in a summary manner, and for allowing several of them to go on simultaneously in the calculating engine. For, if we use simple counting as our only operation, and suppose our engine set to 2312 (say), then, in order to add 3245 to it by mere repetition, we have 3245 unit operations to perform, and this is practically intolerable. If, however, we can separate the counting, so as to count on units to units only, tens to tens only, hundreds to hundreds only, and so forth, we shall only have

$$3+2+4+5=14$$

turns of the handle, as against 3245 turns. In general terms the number of operations will be measured by the sum of the digits of the number, instead of by the actual number itself. This is exactly analogous to what we should do ourselves in ordinary arithmetic in working an addition sum, if we had not learnt the addition table, but had to count on our fingers in order to add. This statement of the work is, however, incomplete. In the first place the convenience of machinery obliges us to provide 10 steps for each figure, whatever it may be, and there must be an arrangement by which the setting of the figure to be added shall cause a wheel to *gain ground* by so many steps as the number indicates, and to *mark time* without gaining ground for the other steps up to 10. Thus, in adding 7 our driver must make a complete turn or 10 steps, equivalent to 1 step of the follower; but only 7 of these steps of the driver must be effective steps, the others being skipped steps. There are various devices for this. One of the simplest and most direct is that used in Thomas's

'Arithmomètre;'* another is the Reducing Bar used by Mr. Babbage.† In the second place, the *carrying* has to be provided for just as in ordinary

FIG. 2.

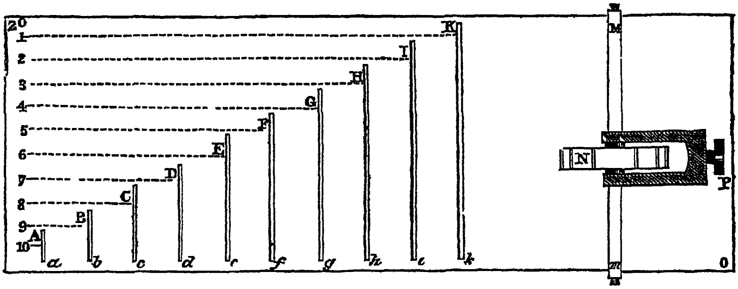
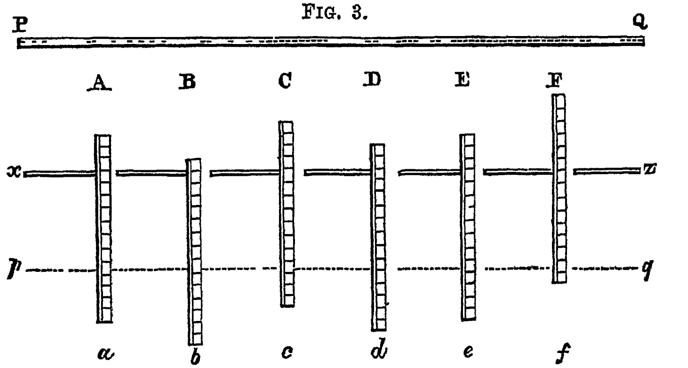


FIG. 3.



addition of numbers. Taking account of all this, it follows that by separating the counting on the whole into counting on figure by figure,

* Let ZO (fig. 2) be a plate with ten ribs of different lengths, Aa, Bb, ... Kk soldered on it. Let Mm be a square axis on which the wheel N is made to slide by the fork P. Then, supposing N to have teeth which can engage in the ribs Aa, &c., when the plate is pushed past the wheel N, the number of teeth through which the wheel N, carrying with it the shaft Mm, is made to rotate, depends upon the number of ribs in which it engages, and this depends upon how far along the axis N is made to slide by means of the fork P. If this fork is set opposite the line marked 3, Mm will turn through a space equivalent to 3 teeth. If a wheel, keyed to the shaft Mm, be geared to other wheels, this enables us to add any digit to any number at a single motion of the plate, by simply changing the position of P to suit the digit required. This is the principle used in Thomas's arithmomètre, only that there the traversing plate is replaced by a rotating cylinder.

† Suppose Aa, Bb, ... Ff (fig. 3) to be a series of racks passing through mortices in a plate xz, and meeting a series of spur-wheels mounted loose on a shaft, so that each wheel gears with one of the racks at the line pq, and that all the whole series can be thrown in or out of gear together. Starting with them out of gear, let the racks be drawn out through the plate xz as indicated. Next throw the shaft pq into gear, and then press a plate PQ against the ends of the racks, pushing them back until the plates PQ and xz meet. Then each wheel on pq will turn through the number of teeth corresponding to the original projection of the racks. In this way, if the wheels on pq stood at any given number, say 543243, we should have added 314236 to them, and they would then stand at the sum of these two numbers, namely, 857479. This, it will be observed, makes no provision for carrying. PQ is

the number of separate steps is reduced from that expressed by the number itself to eleven times the number of its digits; that is to say, for example, the addition of the number 73592 to any other number is reduced from 73592 to 55 steps, and although of this latter some are slipped, there is no gain of time thereby, except in so far as several of the steps may be made simultaneously. The ordinary engines beat the human calculator in respect of adding all the figures simultaneously; but Mr. Babbage was the first to devise a method of performing all the carrying simultaneously too.

Mechanical invention has not yet gone beyond the reduction of the distinct steps involved in the addition of a number consisting of n digits to less than $11n$; practically, from the necessity of accompanying the carrying with a *warning* step, rather more are required.

In all the calculating machines at present known, including Mr. Babbage's analytical engine, multiplication is really effected by repeated addition. It is true that, by a multiplication of parts, more than one addition may be going on simultaneously; but it yet remains true, as a matter of mechanism, that the process is purely one of iterated addition.

By means of reversing wheels or trains, subtraction is as easily and directly performed as addition, and that without becoming in any degree a tentative process. But it is important to observe that the process can be made tentative, so as to give notice when a minuend is, or is about to become, exhausted. This is the necessary preparation for division, which is thus essentially a tentative process. That does not take it out of the power of the machine, because the machine may be, and is, so devised as to accept and act upon the notice. Nevertheless it is a step *alieni generis* from the direct processes of addition, multiplication, and subtraction. It need hardly be stated that the process of obtaining a quotient consists in counting the number of subtractions employed, up to the machine giving notice of the minuend being exhausted.

Another essentially distinct train is involved in the decimal shift of the unit, in all the four elementary rules. This is most simply and most commonly effected by the sliding of an axis or frame longitudinally, after the manner of a common sliding-scale or rule, so as to bring either the figures, or the teeth which represent them, against those to which their decimal places correspond, and to no others. In multiplication and division, this means a shift for each step of the multiplication and division.

II. *Special Characteristics of Mr. Babbage's Analytical Engine.*

1. *The mill.*—The fundamental operation of Mr. Babbage's analytical engine is simple addidition. This and the other elementary rules of subtraction, multiplication, and division, and all combinations of these, are performed in what is called "*the mill.*" All the shifts which have to take place, such as changing addition into subtraction by throwing a reversing train into gear, or the shift of the decimal place, carrying and borrowing, and so forth, are effected by a system of rotating cams acting upon or

the reducing bar. In practice the arrangement is usually circular, the bar PQ revolving about an axis parallel to itself instead of sliding. If the numbeis on the wheels *pq* are placed one way we get addition; if reversed, subtraction. Otherwise we may reverse by introducing an additional set of wheels between the wheels *pq* and the racks.

This is the bare principle, admitting of many transformations, and making, like the other, no provision for carrying.

actuated by bell-cranks, tangs, and other similar devices commonly used in shifting machinery, sometimes under the name of clutches or escapements. These clutches and bell-cranks control the purely additive and carrying processes effected in the additive trains described in the note to § I., and, *being themselves suitably directed*, secure that the proper processes shall be performed upon the proper subject-matter of operation, and duly recorded, or used, as may be required.

2. *The store.*—A series of columns, each containing a series of wheels, constitutes the store. This store, which may be in three or more dimensions, both receives the results of operations performed in the mill, and serves as a store for the numbers which are to be used in the mill, whether as original or as fresh subjects of operation in it. Each column in the store corresponds to a definite number, to which it is set either automatically or by hand, and the number of digits in this number is limited by the number of wheels carried on the shaft of the column. The wheels gear into a series of racks, which can be thrown into or out of gear by means of the cards.

3. *Variable cards.*—All the numbers which are the subject of operation in the mill, whether they are the result of previous operations therein, or new numbers to be operated upon for the first time, are introduced to it in the form of Jacquard* cards, such as are used in weaving. One set of wires or axes transfers the numbers on these cards to the subject of operation in the mill, exactly as similar cards direct which of the warp threads are to be pushed up, and which down, in the Jacquard loom. The mill itself punches such cards when required.

4. *Operation cards.*—A different set of cards selects and prescribes the sequence of operations. These act, not upon the number wheels of the mill or store, but upon the cams and clutches which direct the gearing of these wheels and trains. Thus, in such an operation as $(a\,b + c)\,d$, we should require :—

1st, 4 variable cards with the numbers a, b, c, d.

2nd, an operation card directing the machine to multiply a and b together.

3rd, a record of the result, namely the product $ab = p$, as a fifth variable card.

4th, an operation card directing the addition of p and c.

5th, a record of the result, namely the sum $p+c=q$, as a 6th variable card,

6th, an operation card directing the machine to multiply q and d together.

7th, a record of the result, namely the product $qd=p_2$, either printed as a final result or punched in a seventh variable card.

* In a letter written by Mr. Babbage to Arago in December 1839, the following explanation of the use of these cards is given. It probably conveys the idea in the fewest words possible. It is only necessary to add that their twofold employment embodies the separation of the symbols of operation from those of quantity. "You are aware that the system of cards which Jacquard invented are the means by which we can communicate to a very ordinary loom orders to weave any pattern that may be desired. Availing myself of the same beautiful invention, I have by similar means communicated to my calculating engine orders to calculate any formula however complicated; but I have also advanced one stage further, and I have communicated through the same means orders to follow certain laws in the use of those cards, and thus the calculating engine can solve any equations, eliminate between any number of variables, and perform the highest operations of analysis."

III. *Capability of the Engine.*

It has already been remarked that the direct work of the engine is a combination and repetition of the processes of addition and subtraction. But in leading up to any given datum by these combinations, there is no difficulty in ascertaining tentatively when this datum is reached, or about to be reached. This is strictly a tentative process, and it appears probable that each such *tentamen* requires to be specially provided for, so as to be duly noted in the subsequent operations of the machine. There is, however, no necessary restriction to any particular process, such as division; but any direct combination of arithmetic, such as the formation of a polynomial, can be made to lead up to a given value in such a manner as to yield the solution of the corresponding equation. In any such process, however, it is evident that there can be only (to choose a simile from mechanism) one degree of freedom; otherwise the problem would yield a locus, indeterminate alike in common arithmetic, and as regards the capabilities of the machine. The possibility of several roots would be a difficulty of exactly the same character as that which presents itself in Horner's solution of equations, and the same may be said of imaginary roots differing but little from equality. These, however, are extreme cases, with which it is usually possible to deal specially as they arise, and they need not be considered as detracting materially from the value of the engine. Theoretically, the grasp of the engine appears to include the whole synthesis of arithmetic, together with one degree of freedom tentatively. Its capability thus extends to any system of operations or equations which leads to a single numerical result.

It appears to have been primarily designed with the following general object in view—to be coextensive with numerical synthesis and solution, without any special adaptation to a particular class of work, such as we see in the difference engine. It includes that *à majori*, and it can either calculate any single result, or tabulate any consecutive series of results just as well. But the absence of any speciality of adaptation is one of the leading features of the design.

Mr. Babbage had also considered the indication of the passage through infinity as well as through zero, and also the approach to imaginary roots. For details upon these points we must refer to his 'Passages from the Life of a Philosopher.'

IV. *Present state of the Design.*

The only part of the analytical engine which has yet been put together is a small portion of "the mill," sufficient to show the methods of addition and subtraction, and of what Mr. Babbage called his "anticipating carriage." It is understood that General Babbage will (independently of this report) publish a full account of this method. No further mention of it will therefore be made here.

A small portion of the work is in gun-metal wheels and cranks, mounted for the most part on steel shafts. But the greater part of the wheels are in a sort of pewter hardened with zinc. This was adopted from motives of economy. They are for the most part not cast, but moulded by pressure, and the moulds of most of them are in existence.

A large number of drawings of the machinery are also in existence. It is supposed that these are complete to the extent of giving an account of

every particular movement essential to the design of the engine; but, for the most part, they are not *working drawings*, that is to say, they are not drawings suited to be sent straight to the pattern or fitting shop, to be rendered in metal. There are also drawings for the erection of the engine, and there appears to be a complete set of descriptive notes of it in Mr Babbage's "mechanical notation." There remains, however, a great deal to be done in the way of calculating quantities and proportions, and in the preparation of working drawings, before any work could actually be set in hand, even if the design be really complete. There is some doubt on this point as the matter stands, and it certainly would be unsafe to rely upon the design being really complete, until the working drawings had been got out. Mechanical engineers are well aware that no complex design can be trusted without this test, at least.

It was Mr. Babbage's rule, in designing mechanism, in the first place to work to his object, in utter disregard of any questions of complexity. This is a good rule in all devising of methods, whether analytical, mechanical, or administrative. But it leaves in doubt, until the design finally leaves the inventor's hands in a finished state, whether it really represents what is meant to be rendered in metal, or whether it is simply a provisional solution, to be afterwards simplified.

V. *Probable Cost.*

It has not been possible for us to form any exact conclusion as to the cost. Nevertheless there are some data in existence which appear to fix a lower limit to the cost. Mr. Babbage, in his published papers, talks of having 1,000 columns of wheels, each containing 50 distinct wheels; this apparently refers to his *store.* Besides the many thousand moulded pewter wheels for these, and the axes on which they are mounted, there is the *mill*, also consisting of a series of columns of wheels and of a vast machinery of cams, clutches, and cranks for their control and connection, so as to bring them within the directing power of the Jacquard systems of variable cards and operation cards. Without attempting any exact estimate, we may say that it would surprise us very much if it were found possible to obtain tenders for less than 10,000*l*, while it would pretty certainly cost a considerable sum to put the design in a fit state for obtaining tenders. On the other hand, it would not surprise us if the cost were to reach three or four times the amount above suggested.

It is understood that towards the close of his life Mr. Babbage had contemplated carrying out the manufacture of the engine on a smaller scale, confining himself to 25 figures instead of 50, and to 200 columns instead of 1000 or more. This would of course reduce the amount of the metal-work proportionately, but we do not think that it would materially reduce the charge which we anticipate for bringing the design into working order.

VI. *Strength and Durability.*

The questions of strength and durability had by no means escaped Mr. Babbage's attention, and a great deal of his detail bears marks of having been designed with especial reference to these two points. That was essential in a large and complex engine with some thousands of wheels, all requiring at some time or other, although not simultaneously, to be driven by the means of one shaft. This necessarily throws a great deal of pressure, and also a great deal of wear and tear, on the main driving shaft

and the gear immediately connected with it. We have no means of knowing, in the present state of the design, to what extent Mr. Babbage had succeeded in reducing this, or whether he had always been successful in arranging his cams and cranks so as to secure the best working angles, and to avoid their being jammed at dead points or otherwise. Giving him full credit for being quite aware of the importance of this, we cannot but doubt whether the design was ever in a sufficiently forward state to enable him, or any one else, to speak with certainty on this point. Several of the existing calculating machines show signs of weakness in the driving-pinions.

One of the movements apparently necessary to the tentative processes of the engine is, when the spur-wheels on a given shaft have been brought into certain definite positions depending on previous operations, to bring up a sharp straight edge against them in a plane passing through the axis of the shaft. This pushes some to right and others to left, according to the position of the crown of the tooth relatively to the straight edge. This operation is necessary to secure that the clearance of the different parts of the machinery, whether originally provided in order to allow it to work smoothly, or whether afterwards increased by working, shall not introduce a numerical error into the result. The principle of this operation is used generally throughout the analytical engine. Its consequent effect, both in respect of the work which it throws upon the main driving gear, and of the wear of the parts which it pushes, forms an important element in considering the durability of the machine. This bar also serves the purpose of locking part of the machine when required.

On the other hand, it is to be remarked, that the use of springs has been wholly discarded by Mr. Babbage, as directors of motion, although he occasionally uses them for return motions.

VII. *Probable utilization of the Analytical Engine.*

It has been already remarked that one of the main features of the engine is, that its function is coextensive with numerical synthesis and solution, and that there is an absence of any special adaptation. In thus widening the sphere of its capability, it is made to diverge from the general tendency of mechanical design, which is towards the selection and particularization of the work to be performed, and the restriction of the machinery to one particular cycle of operation, usually within close numerical limits, as well as limited in kind. Nevertheless, modern engineering practice finds ample room for "universal" drills, shaping tools, and other machines having very general adjustments and applications. But it remains practically true that each step of freedom of adjustment is also a step in diminution of special aptitude.

While the analytical engine is capable of turning out a single result, as the combination of a complex series of numbers and operations performed upon them, it can also yield a series of such results in a consecutive form, and thus give tabulated results. Only it is not restricted, as is the difference engine, to the special method of tabulation by finite differences, nor is tabulation its primary function or intention. If its actual capabilities are found to realize the intentions of its inventor, it will tabulate all functions which are within the reach of numerical synthesis, and those direct inversions of it which are known under the name of solutions. It deals, however, with number, and not with analytical form.

Theoretically it might supersede the difference engine, *à majori*; but for reasons already stated, the specialization of the difference engine would probably give it an advantage over the more powerful engine, when the work was specially suited to finite differences.

There would remain much work, tabular and other, for which differences are not very directly suited. Among these may be mentioned the determination of heavy series of constants and of definite functions of them, such as Bernoulli's numbers, Σx^{-n}, coefficients of various expansions of functions, and inversions of known expansions, solutions of simultaneous equations with large numerical coefficients and many variables, including, as a particular, but important case, the practical correction of observations by the method of least squares. If all sorts of heavy work of this kind could be easily and quickly, as well as certainly, done, by merely selecting or punching a few Jacquard cards and turning a handle, not only much saving of labour would result, but much which is now out of human possibility would be brought within easy reach.

If intelligently directed and saved from wasteful use, such a machine might mark an era in the history of computation, as decided as the introduction of logarithms in the seventeenth century did in trigonometrical and astronomical arithmetic. Care might be required to guard against misuse, especially against the imposition of Sisyphean tasks upon it by influential sciolists. This, however, is no more than has happened in the history of logarithms. Much work has been done with them which could more easily have been done without them, and the old reproach is probably true, that more work has been spent upon making tables than has been saved by their use. Yet, on the whole, there can be no reasonable doubt that the first calculation of logarithmic tables was an expenditure of capital which has repaid itself over and over again. So probably would the analytical engine, whatever its cost, if we could be assured of its success.

VIII. *Possible Modification of the Engine.*

Without prejudging the general question referred to us as to the advisability of completing Mr. Babbage's engine in the exact shape in which it exists in the machinery and designs left by its inventor, it is open to consideration whether some modification of it, to the sacrifice of some portion of its generality, would not reduce the cost, and simplify the machinery, so as to bring it within the range of both commercial and mechanical certainty. The "mill," for example, is an exceedingly good mechanical arrangement for the operations of addition and subtraction, and with a slight modification, with or without store-columns, for multiplication. We have already called attention to the imperfection of the existing machines, which show weakness and occasional uncertainty. It is at least worth consideration whether a portion of the analytical engine might not thus be advantageously specialized, so as to furnish a better multiplying machine than we at present possess. This, we have reason to believe, is a great desideratum both in public and private offices, as well as in aid of mathematical calculators.

Another important desideratum to which the machine might be adapted, without the introduction of any tentative processes (out of which the complications of the machinery chiefly arise) is the solution of simultaneous equations containing many variables. This would include

a large part of the calculations involved in the practical application of the method of least squares. The solution of such equations can always be expressed as the quotient of two determinants, and the obtaining this quotient is a final operation, which may be left to the operator to perform by ordinary arithmetic, or which may be the subject of a separate piece of machinery, so that the more direct work of forming the determinant, which is a mere combination of the three direct operations of addition, subtraction, and multiplication, may be entirely freed from the tentative process of division, which would thus be prevented from complicating the direct machinery. In the absence of a special engine for the purpose, the solution of large sets of simultaneous equations is a most laborious task, and a very expensive process indeed, when it has to be paid for, in the cases in which the result is imperatively needed. An engine that would do this work at moderate cost would place a new and most valuable computing power at the disposal of analysts and physicists.

Other special modifications of the engine might also find a fair field for reproductive employment. We do not think it necessary to go into these questions at any great length, because they involve a departure, in the way of restriction and specialization, from Mr. Babbage's idea, of which generality was the leading feature. Nevertheless, we think that we should be guilty of an omission, if we were to fail to suggest them for consideration.

IX. *General Conclusions, and Recommendation.*

1. We are of opinion that the labours of Mr. Babbage, firstly on his Difference Engine, and secondly on his Analytical Engine, are a marvel of mechanical ingenuity and resource.

2. We entertain no doubt as to the utility of such an engine as was in his contemplation when he undertook the invention of his analytical engine, supposing it to be successfully constructed and maintained in efficiency.

3. We do not consider that the possibilities of its misuse are any serious drawback to its use or value.

4. Apart from the question of its saving labour in operations now possible, we think the existence of such an instrument would place within reach much which, if not actually impossible, has been too close to the limits of human skill and endurance to be practically available.

5. We have come to the conclusion that in the present state of the design of the engine it is not possible for us to form any reasonable estimate of its cost, or of its strength and durability.

6. We are also of opinion that, in the present state of the design, it is not more than a theoretical possibility; that is to say, we do not consider it a certainty that it could be constructed and put together so as to run smoothly and correctly, and to do the work expected of it.

7. We think that there remains much detail to be worked out, and possibly some further invention needed, before the design can be brought into a state in which it would be possible to judge whether it would really so work.

8. We think that a further cost would have to be incurred in order to bring the design to this stage, and that it is just possible that a mechanical failure might cause this expenditure to be lost.

9. While we are unable to frame any exact estimates, we have reason

to think that the cost of the engine, after the drawings are completed, would be expressed in tens of thousands of pounds at least.

10. We think there is even less possibility of forming an opinion as to its strength and durability than as to its feasibility or cost.

11. Having regard to all these considerations, we have come, not without reluctance, to the conclusion, that we cannot advise the British Association to take any steps, either by way of recommendation or otherwise, to procure the construction of Mr. Babbage's Analytical Engine and the printing tables by its means.

12. We think it, however, a question for further consideration whether some specialized modification of the engine might not be worth construction, to serve as a simple multiplying machine, and another modification of it arranged for the calculation of determinants, so as to serve for the solution of simultaneous equations. This, however, inasmuch as it involves a departure from the general idea of the inventor, we regard as lying outside the terms of reference, and therefore perhaps rather for the consideration of Mr. Babbage's representatives than ours. We accordingly confine ourselves to the mere mention of it by way of suggestion.

Third Report of the Committee, consisting of Dr. JOULE, Professor Sir W. THOMSON, Professor TAIT, Professor BALFOUR STEWART, *and* Professor MAXWELL, *appointed for the purpose of determining the Mechanical Equivalent of Heat.*

IT will not be necessary to make a long report to the Association this year. Dr. Joule has published a paper, giving *in extenso* the experiments summarized in the last two reports in the 'Philosophical Transactions of the Royal Society,' which was the medium of the publication of his former paper in 1850. The new result, which confirms the old one, gives 772·55 foot-pounds as the equivalent at the sea level and the latitude of Greenwich of the heat which can raise a pound of water, weighed *in vacuo*, from 60° to 61° Fahr. of the mercurial thermometer, where the permanent freezing point is called 32°, and the permanent boiling point of water under a barometrical pressure of 30 inches of mercury raised to 60° Fahr. is 212°. The work at present in hand is a more accurate investigation of the true position of the freezing and boiling points of the thermometers when cleared from the effects of the imperfect elasticity of the glass of which they are constructed. The correction of the above equivalent which may thus accrue is not expected to be of considerable amount.

Report of the Committee, consisting of Professor G. FORBES, Professor Sir WILLIAM THOMSON, *and* Professor EVERETT, *appointed for the purpose of making arrangements for the taking of certain Observations in India, and Observations on Atmospheric Electricity at Madeira.*

THE Committee has purchased three electrometers. These have been given, one to Surgeon-Major Johnson, in India; the second to Mr. Michie Smith, in India; and the third to Dr. Grabham, in Madeira. Surgeon-Major Johnson was engaged in the frontier war in India; and Dr. Grabham has hitherto been too much occupied to make observations, while Mr. Michie Smith has not yet had time to furnish any. So that up to the present time no observations have been received. Your Committee feel confident of obtaining results from Mr. Smith, and hope also from the other observers, but in the event of their being unable to furnish regular observations, your Committee would get the electrometers back and make them available for other persons. They propose that the Committee should be reappointed.

Report of the Committee, consisting of Professor Sir WILLIAM THOMSON, Professor CLERK MAXWELL, Professor TAIT, Dr. C. W. SIEMENS, Mr. F. J. BRAMWELL, Mr. W. FROUDE, *and* Mr. J. T. BOTTOMLEY, *for commencing Secular Experiments upon the Elasticity of Wires. Drawn up by* J. T. BOTTOMLEY.

THE Committee have to report that the arrangements for suspending the wires for secular experiments on elasticity are now complete; and that within the last few days two wires, one of palladium, and the other of platinum, have been suspended in their places.

An iron tube has been erected in one of the rooms in the tower of the University buildings in Glasgow. It is 60 feet long, 9 inches wide, and $4\frac{1}{2}$ inches deep from face to back. It is of rectangular section, in lengths of 6 feet; and it is supported by being firmly attached to the heavy outer stone wall of the tower.

At the top of the tube there is a heavy gun-metal plate, which is supported independently of the iron tube; and from this plate the wires under examination are to be suspended, as well as additional wires to be used for carrying additional comparison marks. With this arrangement no yielding of the supporting plate that may take place will introduce errors into the results of measurement of the lengths of the wires; for the point of support of the wire carrying comparison marks will experience the same amount of lowering, due to the yielding, as is experienced by the wire to be measured against these marks. The gun-metal plate has been pierced with three rows of holes through which the wires are to pass. The holes are trumpeted at each end so as to avoid sharp contact with the wires, and the rows are arranged so that the wires shall hang down in planes parallel to the face of the tube. It has not yet been decided what is the best way of fixing the upper ends of the

wires above the gun-metal plate, or of attaching the weights to their lower ends. No thoroughly satisfactory mode of attachment has yet been found. In the course of experiments which have been carried on at Glasgow on the breaking weight, and the Young's modulus of elasticity of the gold, platinum, and palladium wires, which it is intended shall be first suspended for examination, several modes of suspension have been tried; but it has not been found possible to make sure of avoiding very considerable weakening of the wire at the points of attachment at the ends.

At the bottom of the iron tube there is a window of plate glass through which the lower parts of the wires can be viewed, and the window can be drawn up so as to allow of the lower parts of the wires being reached.

In front of the window a strong gun-metal table is set up. It is supported, independently of the iron tube and of the floor of the room, on iron brackets fixed to the stone wall of the chamber, and is very carefully levelled. On this table a cathetometer is carried, by means of which marks on the wires are to be observed. The cathetometer moves on the table parallel to the planes of the rows of wires. It has the two back feet of the triangular sole-plate on which it is supported movable in a V-groove cut in the table, the third foot resting on the plane upper surface. There is also a slot cut in the table through which a screw passes up from below to the sole-plate of the cathetometer, and by means of this screw the cathetometer can be clamped in any required place.

The cathetometer is a small instrument which has been constructed by Mr. James White, of Glasgow, for the purpose of these experiments. The main pillar is 1 foot high. It is supported on a sole-plate having three levelling screws. The telescope or microscope, having cross fibres, is raised or lowered on this pillar on a proper geometrical slide, and has also a lifting screw in connection with a vernier for giving fine adjustment. The vertical pillar is carefully graduated; and by means of this scale the differences of levels of proper marks put upon the wires are to be determined.

The arrangements have only been completed within the last few days. They require to be carefully tested in several points, and particularly the cathetometer requires careful examination. There is every reason, however, to expect that the work will turn out quite satisfactory. As soon as possible the work of testing will be completed and wires suspended, measured, and marked.

During the past year experiments in connection with this investigation have been carried on in the laboratory of the University of Glasgow, on the breaking-weights and elastic properties of various wires. In the first place the breaking-weights and the Young's modulus, or modulus of elasticity for longitudinal pull, have been determined for the gold, platinum, and palladium wires, with which it is proposed that the secular experiments on elasticity shall commence. A large number of experiments on the effect of stress, maintained for a considerable time, in altering the breaking weight and the extension under increased stress of various wires, have been carried on. Soft iron wire, steel wire, and tin wire in particular, have been experimented upon, and already some interesting results have been obtained, showing that prolonged application of stress certainly produces a noticeable effect.

Report of the Committee on the Chemistry of some of the lesser-known Alkaloids, especially Veratria and Bebeerine; the Committee consisting of W. CHANDLER ROBERTS, *F.R.S.* (*Sec.*), Dr. C. R. ALDER WRIGHT, *and* Mr. A. P. LUFF.

THE work at present completed has led to conclusions very diverse from those arrived at by previous experimenters who have partially examined the alkaloids contained in the seeds of *Veratrum Sabadilla* (*Asagræa officinalis*); in consequence, other species of the Veratrum family (such as *Veratrum album*) are being investigated with a view to finding out how far the alkaloids therein contained are related to the bases found in *V. Sabadilla*. These investigations being at present incomplete, it would be premature to report on them otherwise than in general terms. The same remark applies to Bebeerine; the experiments with this alkaloid having at present led to little that is definite.

Amongst other pharmaceutical and chemical researches on the alkaloids of *Veratrum Sabadilla* may be briefly mentioned those of Pelletier and Caventou, who isolated in 1819 an amorphous alkaloid or alkaloidal mixture fusing at 50°; and of Couerbe, who, in 1834, obtained three alkaloidal bodies, one of which was amorphous, but yielded a crystalline sulphate and hydrochloride; to this base he applied the term *Veratrine*. The second base isolated was soluble in water, and crystallisable therefrom, and was termed by him *Sabadilline*; whilst the third substance was soluble in water, but non-crystallisable; this was termed by Couerbe *Hydrate of Sabadilline*. Later on, in 1855, Merck isolated from the amorphous mixture sold under the name of "Veratria" an alkaloid readily crystallisable from alcohol, but forming salts quite uncrystallisable, the aurochloride excepted. Notwithstanding that this base differed entirely in properties from the Veratrine of Couerbe, Merck applied to it the same name, "Veratrine," and ascribed to it the formula $C_{32}H_{52}N_2O_8$. In 1871 Weigelin, working in Dragendorff's laboratory, obtained from *V. Sabadilla* three alkaloidal substances, one of which was apparently the Veratrine of Merck in an impure state; whilst the other two were soluble in water, and were termed respectively *Sabadilline* and *Sabatrine*. Within the last year or two, Schmidt and Köppen have re-examined the so-called "Veratria" of commerce, and have obtained from it and from Sabadilla seeds direct a crystallisable base, fusing at 205°, and evidently identical with the Veratrine of Merck. To this, however, they assign the formula, $C_{32}H_{50}NO_9$, somewhat different from Merck's formula, especially in the nitrogen.

On working up a quantity of crushed Sabadilla seeds by percolating with alcohol acidulated with tartaric acid, evaporating to a small bulk, adding water, filtering from resin, and extraction of alkaloids by adding soda and shaking with large bulks of ether, we have obtained an alkaloidal mixture from which, by further operations, there have been separated three distinct alkaloids. As the process employed has been already described at length ('Journal of the Chemical Society,' 1878), it is unnecessary to repeat it here.

One of these alkaloids melted at 205°–206°, crystallised finely from alcohol, formed a crystallised aurochloride, but no other crystalline salts, and was evidently identical with the Veratrine of Merck. The second did not crystallise itself, but formed a well-crystallised sulphate and hydro-

chloride, and was apparently identical with the Veratrine of Couerbe. The third neither crystallised nor yielded crystalline salts, but was sharply distinguished by its sparing solubility in ether. Nothing agreeing in properties with the 'Sabadilline' of Couerbe and of Weigelin could be found either in the alkaloids extracted from the seeds, in a quantity of the alkaloidal mixture sold commercially as "Veratria," or, finally, in a substance purchased from Messrs. Burgoyne and Burbidges (Kahlbaum's agents) as being Sabadilline itself! This last substance consisted entirely of the third base above mentioned, the only point of similarity between it and 'Sabadilline' being very sparing solubility in ether.

Each one of the three bases was saponified by alcoholic soda, the first and third apparently forming the same acid product which has been identified with the *Methylcrotonic Acid* of Frankland and Duppa, and with the *Cevadic Acid* of Pelletier and Caventou; the second base yielded, by similar treatment, *Dimethylprotocatechuic Acid*, identical with that similarly obtained from pseudaconitine, and, as Körner has shown, identical with that isolated by Merck from *V. Sabadilla* seeds, and termed by him *Veratric Acid*. From these circumstances we propose to assign to the three bases respectively the following names. The formulæ attached are those derived from our own analyses; in the case of the first base our numbers are practically identical with those of Merck and of Schmidt and Köppen, Merck's nitrogen determination excepted.

(1.) *Cevadine*, $C_{32}H_{49}NO_9$; the "Veratrine" of Merck. We term this Cevadine because the prior right to the name, "Veratrine," rests with Couerbe's base (*vide infra*), and because it forms Cevadic acid on saponification, the reaction being

$$C_{32}H_{49}NO_9 + H_2O = C_5H_8O_2 + C_{27}H_{43}NO_8.$$

(2.) *Veratrine*, $C_{37}H_{53}NO_{11}$; the 'Veratrine' of Couerbe. We term this Veratrine because, as just stated, the prior right to the name belongs to it, and because it forms Veratric acid on saponification; the reaction being

$$C_{37}H_{53}NO_{11} + H_2O = C_9H_{10}O_4 + C_{28}H_{45}NO_8.$$

(3.) *Cevadilline*, $C_{34}H_{53}NO_8$. We term this Cevadilline because it exhibits a certain amount of similarity to the "Sabadilline" described by Weigelin, and because it appears to form Cevadic acid on saponification.

The basic complementary products formed by saponification from these three bases we propose to term respectively *Cevine*, *Verine*, and *Cevilline*. Cevine and Verine are non-crystalline, and much resemble one another.

When Cevadic acid is heated with fusing potash, hydrogen is evolved, and acetic and propionic acids formed. As Cevadic acid melts at 64°–65°, its identity with the Methylcrotonic acid of Frankland and Duppa is thereby demonstrated, this acid having been found to melt at 62° (F. and D.); whilst Angelic acid, which also forms acetic and propionic acids by fusion with potash, melts at 45°.

When Cevadine is heated to 100° with excess of benzoic anhydride, it forms a benzoylated derivative, *Benzoyl Cevadine*, in virtue of the reaction

$$C_{32}H_{49}NO_9 + (C_7H_5O)_2O = C_7H_6O_2 + C_{32}H_{48}(C_7H_5O)NO_9.$$

It results from these experiments that the following "structural" formulæ may be assigned, since Methylcrotonic acid is indicated by $C_2H_4 = C(CH_3) - CO.OH$:—

Cevadine, $(C_{27}H_{41}NO_6) \begin{array}{l} -OH \\ -O.CO.C(CH_3){=}C_2H_4 \end{array}$

$= C_{27}H_{41}NO_6) \begin{array}{l} -OH. \\ -O.C_5H_7O \end{array}$

Benzoyl Cevadine, $(C_{27}H_{41}NO_6) \begin{array}{l} -O.C_7H_5O \\ -O.CO.C(CH_3){=}C_2H_4 \end{array}$

$=(C_{27}H_{41}NO_6) \begin{array}{l} -O.C_7H_5O. \\ -O.C_5H_7O. \end{array}$

Cevine, $(C_{27}H_{41}NO_6) \begin{array}{l} -OH. \\ -OH. \end{array}$

Veratrine, $(C_{28}H_{44}NO_7).O.CO.C_6H_3(O.CH_3)_2$.

Verine, $(C_{28}H_{44}NO_7).OH$.

A large proportion of the alkaloidal mixture obtained from *V. Sabadilla* seeds, even with most careful working, so as to avoid as much as possible alteration of alkaloids during extraction, refuses to crystallise either as free base or as a salt. This has been considered by Weigelin and by Schmidt and Köppen to indicate the existence of an isomeric amorphous modification of Cevadine (the Veratrine of Merck) ; another modification being also considered to exist, soluble in water, and obtainable from this amorphous mixture by treatment with water. We find, however, that the amorphous mass is simply a mixture of Cevadine and Veratrine, the one base preventing the other from crystallising in the free state, and the other preventing the sulphate, or other salt of the first, from crystallising readily, and the crystallisability being further hindered by the presence of more or less Cevine, Verine, &c., formed by partial spontaneous saponification. This latter, too, is the cause of the partial solubility of the amorphous mixture in water, the cevadates and veratrates formed by the partial change being readily soluble in water.

Doubtless the "Sabatrine" of Weigelin was a mixture of saponification and alteration products. Whether his Sabadilline was a definite precontained principle or not we cannot say, not having been able to find it, even in the preparation sold as being the body itself.

In pursuance of these results, we are investigating the alkaloids of *V. album* roots. These have been already shown by Pelletier and Caventon, Simon, Mitchell, and others, to contain at least two alkaloids, one being non-sternutatory, crystallisable from alcohol, and forming very sparingly soluble salts with certain mineral acids, *e.g.*, sulphuric acid ; another being non-crystalline, but powerfully sternutatory. Since both the Cevadine and Veratrine above described are powerfully provocative of sneezing and tickling of the throat when inhaled as dust, it would seem probable that the former alkaloid, *Jervine* (which has never been found in *V. Sabadilla* seeds), is utterly distinct in its nature from the latter one. Our experiments, at present far from complete, lead us to believe that "Jervine" is not a single alkaloid, but a mixture of two or more closely alike in many respects, and quite dissimilar from the sternutatory base; whilst the latter is a mixture of bases, of which one is, if not identical with the Veratrine above described, closely allied to it, as on saponification the mixture forms a small quantity of Veratric acid.

Report on the best Means for the Development of Light from Coal-Gas of different qualities, by a Committee consisting of Dr. WILLIAM WALLACE (*Secretary*), Professor DITTMAR, *and* Mr. THOMAS WILLS, *F.C.S., F.I.C.*

PART I.—*Drawn up by* Dr. WALLACE.

THE fact has long been recognised that the illumination afforded by the combustion of coal-gas depends, to a large extent, upon the way in which it is burned. Setting aside, for the present, all reference to the different theories of Davy, Frankland, Heumann, and others, as to the source of the illumination, whether from solid highly-heated particles of carbon or from incandescent gases, the fact is patent that a given quantity of gas may be burned under different conditions, so as to yield widely different illuminating effects. For example, a gas made from bituminous coal gave, when burned by Sugg's Improved London Argand at the rate of 5 cubic feet per hour, the light of 14·81 candles. The same quantity burned by a union jet at ·5 inch (water) pressure gave 11·46 candles; and by a union jet at 1·5 inch pressure 3·66 candles; these quantities corresponding to 100, 77, and 25. Pattinson states that burners are in extensive use in Newcastle which, for 5 cubic feet of gas, give a light equal to only $3\frac{3}{4}$ candles, which gas, burned in a good Argand, gives for the same consumption $17\frac{3}{4}$ candles, and in good union or fishtail burners $12\frac{1}{2}$ candles. In the case of cannel-gas, the variations are not so extensive; but the following illustrates the effect of pressure alone in influencing the light obtained, the burners being of the same kind in each case, but with orifices suited to deliver 5 cubic feet of gas at the different pressures: at $\frac{1}{2}$-inch pressure a union jet of the best construction gave a light equal to 28·47 candles, while at $1\frac{1}{2}$-inch pressure the light from an equally good union jet was 21·14 candles; these numbers being in the proportion of 100 to 74. In these instances the quantities of gas were the same (5 cubic feet per hour); but if we take smaller quantities of gas, and calculate the results to 5 feet, the numbers obtained are still more startling. The following cases are quoted from Wallace's paper on the "Economic Combustion of Coal-Gas," * all the burners used being Bray's "adamas-tipped" union jets for cannel-gas. A No. 0 at $1\frac{1}{2}$-inch pressure burned 2 cubic feet per hour, and gave a light of 3·5 candles, or for 5 cubic feet per hour, 8·8 candles; a No. 8 at 1-inch pressure burned 7·1 cubic feet per hour, and gave 45·4 candles, or for 5 cubic feet, 32 candles. Between ordinary working limits of pressure and with equally good burners, we have, therefore, a given quantity of gas (5 cubic feet per hour) giving, in the one case, 32 candles, and in the other 8·8; or in the proportion of 100 to $27\frac{1}{2}$. The loss of light here shown, amounting to $72\frac{1}{2}$ per cent. of the whole, is exceeded when still higher pressures are used, and it is greater with common than with cannel-gas. A remarkable effect is obtained with a mixture of cannel-gas with about twice its bulk of air. At a low pressure in an Argand jet with large holes it gives a fairly luminous flame, while, at a high pressure (3 or 4 inches), although the quantity of gas consumed is three times as great, the flame is almost totally non-luminous, and has a greenish tint. The gas, used somewhat extensively in the United States,

* Transactions of the Philosophical Society of Glasgow, 1873–4. Journal of Gas Lighting, 1874.

made by saturating air with petroleum spirit, requires to be burned at a pressure not exceeding ·1 of an inch, which can be obtained only with an Argand with very large holes, or a batwing of peculiar construction, called the "American Regulating Batwing." At ordinary pressures, such as are used for coal-gas, there is scarcely any light, and the flame keeps about a quarter of an inch or more above the burner.

It is not only on the score of economy that it is desirable to burn gas in such a manner as to afford the greatest possible amount of light. The burning of a moderate sized jet of gas produces as much carbonic anhydride as the breathing of two grown-up men, and as, in an ordinary apartment, we have usually from three to six of these, the air becomes vitiated with remarkable rapidity. It is therefore desirable, in relation to health, to obtain the illumination we require with the least possible expenditure of gas. The sulphur in gas is a very serious drawback to its use. In burning it is, no doubt, converted chiefly, if not entirely, into sulphurous anhydride; but it is soon converted into sulphuric acid, which attacks with avidity all the more readily destructible articles in the apartment. So far back as forty years since the effects of the sulphuric acid arising from the combustion of gas upon the binding of books and many articles of furniture was noted, and recent experiments have shown that leather, paper, &c., in ill-ventilated apartments exposed to the emanations from burning gas for a series of years contain very large quantities of sulphuric acid. One of us has had occasion recently to investigate the action of burning gas upon cotton goods stored in warehouses in London, Manchester, and other cities and towns, and found that, in some cases, a few months are sufficient to affect certain colours; while within a year enough sulphuric acid is absorbed to seriously injure the strength of the fabrics. No doubt the true remedy for this evil is to ventilate the warehouses; but it is obvious that if the gas were burned in an advantageous manner, and the quantity reduced to one-half or one-third, the damaging effects would be proportionately lessened.

There are several distinct qualities of gas in use in this country. The best may be described as Scotch cannel-gas, as it is made only in Scotland, where the illuminating power varies from 24 to 30 standard for 5 cubic feet per hour, consumed in a union or fishtail jet; the average may be fairly stated as 26 candles. In London a cannel-gas is used in small proportion, the illuminating power of which is about 23 candles; and in Liverpool, Manchester, Carlisle, and probably some other towns, an intermediate gas is manufactured, the illuminating power of which is about 20 candles. The common gas in London and most other English and Irish towns has an illuminating power of 14 to 16 candles. In the present Report it is our intention to confine our investigations to two qualities of gas, *i.e.*, cannel-gas of 26 candles, and common gas of 16 candles illuminating power. The photometric results in each case will be calculated to these standards, although in the actual experiments the gas may have been a little higher or lower in quality. In the case of cannel-gas the standard is found by testing the gas by a union jet consuming 5 cubic feet at a pressure of ·5 of an inch; while the common gas is tested by Sugg's London Argand, consuming 5 cubic feet per hour at a pressure of about ·05 of an inch. The best means at present known of burning each quality of gas will be pointed out, and tabulated results will be given, containing the details of the testings of the different kinds of burners under varying conditions of pressure.

The burners at present in use may be divided into the four following classes:—1st, Cockspur or rattail; 2nd, Union or fishtail; 3rd, Batwing; 4th, Argand. Of each of these there are a number of modifications.

The cockspur or rattail burner is the simplest possible form of gas jet, and it was at one time the only one used for burning gas. It may be made by simply drawing out a piece of glass tube and breaking off the point so as to leave an orifice, having a diameter of 1 millimetre or less; but it is usually constructed of cast iron, which is drilled out as wide as possible from the bottom, leaving only a thin shell, which is then bored with a fine drill. Two sizes of these were tested, No. 1 having an orifice of about ·6, and No. 2 of about ·75 millimetre. These jets are used in Glasgow for lighting common stairs, and the larger size were formerly employed for street lamps, but are now discarded in favour of union jets. The following are the results with 26-candle gas:—

Burner No.	Pressure in inches	Length of flame in inches	Gas per hour, cubic feet	Illuminating Power, in Standard Candles	Illuminating Power of 5 cubic feet per hour, Candles
1	·5	2	·45	·89	9·9
1	1	$3\frac{1}{2}$	·60	1·69	14·1
1	1·5	$4\frac{1}{8}$	·90	2·40	13·3
2	·5	$7\frac{7}{8}$	·80	2·49	15·6
2	1	$5\frac{7}{8}$	1·13	3·55	15 7
2	1·5	$3\frac{1}{2}$	1·45	4·53	15·6

These figures show that even with the larger jet no more than 60 per cent. of the real value of the gas can be obtained. Various modified forms of the jet were tried, some having "adamas" tips, and contracted at the bottom or otherwise obstructed, so as to diminish the pressure at the point of ignition, but they did not show any marked superiority over those referred to above.

When two rat-tails are held at a right angle to one another, the lights coalesce and form a flat sheet of flame. When this discovery was first made, two burners were fitted up in this way; but soon a single burner was contrived which combined the two, and hence was called a "union" jet: it is also known as a fishtail, from the resemblance of the flame to the tail of a fish. It is a short cylindrical tube with a flat top in which the two orifices are drilled at about 90° to one another, and meeting in the centre. The union jet is much improved by substituting for the metal top porcelain or stoneware, the principal advantage gained being that the orifices remain clean and constant in size, while those of iron gradually rust up and require to be frequently cleaned in order to give a satisfactory light, and are consequently enlarged. Some fishtail burners are made entirely of a kind of stoneware or of steatite, but these are troublesome to remove when they get broken. The best form of burner is that with a brass body and porcelain top. Such burners are made by Leoni of London, Bray of Leeds, and other makers; but usually with some means of reducing the pressure. The fishtail burner is not suited for burning at a high pressure, under which the two flames refuse to spread out into a flat sheet but form an irregular flame, at the same time emitting a most disagreeable hissing or blazing sound. This effect

may also result from other causes—such as a sharp bend in the gas supply tube, a speck of dust in one of the orifices of the burner, or, in fact, anything that disturbs the even and quiet flow of the gas. One singular example of this is the following:—If a union jet is burning 5 cubic feet of gas at ·5 inch pressure, and a portion of the gas is led away by means of a tube inserted a few inches below the flame, the flame, although diminished in volume, immediately begins to blow.

In testing flat flames the custom has invariably been to present the flat side to the disc of the photometer; but although the results so obtained are satisfactory in comparing one flat flame with another, they cannot fairly be compared with rattail or Argand flames, which give an equal light all round. The edge of a flat flame gives considerably less light than the side, but the difference between the two depends very much upon the richness of the gas, or, in other words, the opacity of the flame. A flame of gas of low quality is so transparent that an ordinary newspaper can be read through it; but this cannot be done with a flame of cannel gas except at the lower portion, which in any case offers scarcely any obstruction to the passage of light. The following example may be given:—A union jet consuming 5 cubic feet of cannel-gas at ·5 inch pressure gave a light of 27 candles when tested in the ordinary manner with the flat side towards the photometer disc, but the edge gave only 23 candles, and when rotated so as to give the flame in every position the average result was, as nearly as possible, 26 candles, showing that the ordinary test gave one candle too much, or nearly 4 per cent. In the case of paraffin flat-flame lamps, the difference between the front of the flame and the average all round varies from 4 to 10 per cent. In the latter case the flame is intensely opaque and of a deep yellow colour. All the figures given in this report refer to the flat side of the flame; and this must be borne in mind in comparing flat with round flames.

The following table gives the results obtained with Bray's union jets without obstruction to retard the flow of the gas and reduce its pressure; gas by ordinary test 26 candles:—

	At ·5 inch Pressure			At 1 inch Pressure			At 1·5 inch Pressure		
	Gas per hour	Illuminating Power	I. P. per 5 cubic feet	Gas per hour	Illuminating Power	Five cubic feet	Gas per hour	Illuminating Power	Five cubic feet
0	1·15	1·96	8·52	1·55	2·35	7·6	1·8	2·45	6.8
1	1·15	3·77	13·00	2·15	5·28	12·28	2·85	5·47	9·6
2	1·7	4·85	14·27	2·5	6·71	13·48	3·1	7·62	12·3
3	2·35	8·98	19·10	3·1	11·73	17·25	4·3	13·67	15·9
4	2 85	11.97	21·00	4·05	15·41	19·06	5·0	16·62	16·62
5	3·25	13·84	21·30	4·5	18·78	20·87	5·55	21·90	19·73
6	4·1	19·6	23·90	5·7	25·60	22·46		Gas blows	
7	4·75	21·76	26·00		Gas blows			Do.	
8	5	26	26·00		Do.			Do.	

This table gives instructive information as to the effects of mass or quantity of gas, and of pressure. As regards mass, we see that at the same pressure the light afforded by 5 cubic feet of gas per hour varies from $8\frac{1}{2}$ to 26 candles, according to the quantity burned; the lowest

result being obtained with about 1 cubic foot per hour, and the highest with 5 cubic feet. This last result, *i.e.*, 26 candles for 5 cubic feet of gas per hour, burned in a union jet at ·5 inch pressure, is taken as the standard of comparison in all the experiments in cannel-gas. The ratio of illuminating power to quantity is nearly the same at higher pressures, and there is no difficulty in deducing the general law that the value in illuminating effect per cubic foot of gas increases with the mass of the flame.

The effects of pressure are not less striking, and might have been more so had the gas been tested at lower pressures than ·5 inch and higher than 1·5 inch. The results obtained with a jet consuming 5 cubic feet per hour gave 26 candles at the low pressure and only 16·6 at 1·5 inch, showing a loss of lighting power amounting to about 36 per cent.; 3 feet per hour, calculated to 5 feet, gave at the low pressure 21 candles, at the high pressure 12·3 candles; the burner being a No. 4 in the one case and a No. 2 in the other. The medium pressure gave results intermediate between these. At the higher pressures some of the larger-sized burners became useless, as already explained.

As in practice it is found impossible to distribute gas at a pressure of less than 12 or 15 tenths of an inch of water, various contrivances for breaking the force of the gas have been invented. Among union jets of this kind, the simplest, perhaps, is that of Leoni, consisting of a brass and an iron tube which fit into one another, and between which a thin film of cotton wool is placed. This is a very good burner, but it cannot be depended upon for delivering exact quantities of gas. Bray has constructed a very good burner similar to those already mentioned, but having a double ply of cotton cloth stretched across a metal ring placed in the tube, in order to reduce the pressure. The same manufacturer has more recently invented another burner in which the reduction of pressure is attained by passing the gas through an orifice in a porcelain plate cemented into the lower part of the burner. He calls these special burners, and they are of two kinds—one intended for general use and the other for street lamps, in which the orifices are somewhat smaller, and in which, consequently, the pressure is further reduced. Morley's patent burner is of brass and vase-shaped, with a porcelain top, and at the bottom one or two small orifices in the metal for admitting the gas. Williamson's jet is similar in principle, but more complicated in construction. Da Costa's burner consists of a hollow vase stuffed with iron turnings, into which an ordinary iron union jet is screwed. There are others, but all have the same object in view; and the simpler and cheaper burners, such as Bray's, accomplish it as successfully as those of more complicated construction, and these have, therefore, been selected for a series of comparative trials, all being made with 26 candle gas. Some of the burners referred to are called regulators, but this is a mere name, for it is obvious that they merely obstruct the flow of the gas, the quantity delivered rising as the pressure is increased. In Bray's special burners the two holes forming the "union" jet are placed at an angle of about 120°.

BRAY'S "REGULATOR" UNION GAS JETS FOR CANNEL-GAS.

	At ·5 inch pressure			At 1 inch pressure			At 1·5 inch pressure		
	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet per hour	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet
0	1	2·72	13·6	1·5	3·13	10·4	2	3·21	8
1	1·15	3·75	16·3	1·8	4·3	11·9	2·45	4·4	9
2	1·5	5·63	18·7	2·3	7·25	15·8	3	7·6	12·6
3	1·8	7·97	22·1	2·75	10·11	18·4	3·55	11·37	16
4	2·4	11·26	23·4	3·6	15·21	21·1	4·3	15·32	17·8
5	2·6	12·76	24·5	4·35	20·4	23·4	5·1	22·19	21·7
6	3·15	15·95	25·3	4·95	25·42	25·7	5·8	27·51	23·8
7	3·8	20·07	26·4	6·05	32·75	27·1		Gasblows	
8	4·7	24·76	26·3	7·1	40·63	28·6		Do.	

In both series of the special burners, in which the pressure is much reduced, the best results are obtained at 1 inch pressure, while at ·5 inch the flames are sluggish, and in some cases show a tendency to smoke.

Mr. Holdsworth, of Bradford, has introduced a simple arrangement which he calls a gas feeder, which has been adopted rather extensively in the manufacturing towns of Yorkshire. It is simply a little wedge-shaped piece of lead pierced in the centre with a hole the area of which is less than that of the holes in the burner, and this is fixed in the gaspipe several inches from the burner. Several sizes are made to suit varying circumstances of local pressure, as well as different sizes of burners, and, if fitted up by an intelligent workman, they accomplish the end in view very successfully.

BRAY'S "SPECIAL" UNION JETS FOR GENERAL USE.

	At ·5 inch pressure			At 1 inch pressure			At 1·5 inch pressure		
	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet
0	1·44	5·51	19·13	2·16	9·22	21·31	2·59	10·80	20·85
1	1·55	6·11	19·71	2·36	10·33	21·88	2·87	12·00	20·91
2	1·86	7·50	20·16	2·76	12·38	22·43	3·36	14·51	21·59
3	2·10	8·90	21·19	3·10	14·27	23·01	3·74	17·29	23·11
4	2·44	10·94	22·42	3·62	17·69	24·43	4·41	20·83	23·60
5	2·71	13·39	24·70	4·13	21·13	25·58	5·16	26·17	25·36
6	3·12	15·12	24·71	4·76	24·40	25·63	5·71	28·66	25·09
7	3·63	18·43	25·39	5·51	28·65	26·00	6·70	31·33	25·62
8	4·28	22·26	26·00	6·39	31·37	26·89	7·92	40·67	25·67

BRAY'S "SPECIAL" UNION JETS FOR STREET LAMPS.

	At ·5 inch pressure			At 1 inch pressure			At 1·5 inch pressure		
	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet
0	1·30	4·85	18·65	1·96	8·22	20·97	2·34	9·70	20·73
1	1·46	6·04	20·68	2·21	9·57	21·65	2·63	11·45	21·77
2	1·73	7·28	21·04	2·56	12	23·44	3·01	11·86	24·68
3	2·07	9·36	22·61	3	14·64	24·40	3·57	17·63	24·69
4	2·24	10·73	23·95	3·33	16·57	24·88	4·05	20·39	25·17
5	2·68	13·15	24·53	4·08	21·17	25·94	4·85	25·67	26·16
6	2·97	14·77	24·86	4·45	23·73	26·66	5·37	28·87	26·88
7	3·44	17·37	25·25	5·31	28·26	26·61	6·13	31·32	26·69
8	3·84	19·21	25·01	5·92	31·22	26·37	7·23	37·32	25·81

Many years ago Mr. Scholl, of London, adopted the system of placing a small plate of platinum between the two orifices of the union jet, the result being that the initial velocity with which the gas escapes is spent by striking against this plate, and the gas ascends in a somewhat sluggish flame, which, in the case of cannel-gas, has a tendency to smoke, and is easily blown about by currents of air. This is the case also with all union jet flames burned at very low pressures, and practically a jet of this kind cannot be burned much below 3 or 4 tenths for small sizes and 5 tenths for large sizes consuming 4 or 5 cubic feet per hour. Scholl's "perfector," as he has called it, has been used extensively in London and other towns for common gas, but it is not suitable for the richer gas used in Scottish towns.

A flame formed by a jet of gas issuing with considerable velocity possesses a certain degree of stiffness, and resists, to some extent, the influence of currents of air. This is particularly necessary in the case of cannel-gas, since, whenever the flame is much deflected by air currents, a portion of the carbon arising from the heating of the richer hydrocarbons (*e.g.*, olifines, benzole, &c.) passes off unconsumed, and a smoky flame is the result. In practice it is necessary to sacrifice a certain proportion of the possible illuminating value in order to give the flame sufficient stiffness to resist currents of air.

Next to the union jet, the "batwing" is that most commonly used for burning gas. It is simply a little tube closed at one end in which a straight slit is cut, varying in breadth from about two-tenths to one millimetre. It is made of cast iron, brass, porcelain, or steatite; the best form being that having a brass body and steatite top. The flame of the batwing is wider and shorter than that of the union jet, and in order to be equally effective requires to be burned at lower pressures. It is particularly adapted for large flames burning from 3½ to 5 cubic feet of gas per hour. With rich cannel-gas (25 to 30 candles) it gives results at least equal to the union jet, and with gas of 18 to 22 candles it is decidedly superior.

The following table gives the results of tests of a series of steatite batwing burners manufactured in Germany—gas 26 candles:—

No. of Burner	At ·5 inch pressure			At 1 inch pressure			At 1·5 inch pressure		
	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet
2	1·1	4·24	19·27	2·35	9·05	19·25	3·15	11·56	18·35
3	1·45	5·68	19·58	2·65	10·02	18·90	3·55	13·2	18·59
4	1·9	8·76	23·05	3·1	12·71	20·50	4	15·41	19·26
5	3·4	16·18	23·80	5·2	24·07	23·14		Gas blows	
6	4·05	19·09	23·57		Gas blows			Gas blows	

The considerable loss of light experienced when gas is consumed in batwing burners at any but comparatively low pressures has given rise to many efforts to combine with the jet an apparatus to reduce the pressure of the gas before it issues from the narrow slit. Various burners having obstructions have been constructed, of which Brönner's is one of the best known. It consists of a somewhat pear-shaped brass body, with a steatite top similar to those of which the results are given above, and at the bottom a small piece of steatite in which is an oblong slit. There are, for cannel-gas, six sizes of bodies, the sizes depending upon the area of the slits; and five sizes of tops, and as these screw into one another, there are thirty possible combinations. In none of these combinations does the pressure of the gas at the point of ignition exceed ·5 of an inch with an initial pressure of 1·5 inch, while in some it is only ·2, and in some it is so low that the flame smokes and is useless. The rate of combustion is dependent on these conditions—1st, the area of the opening at the bottom; 2nd, the area of the slit of the burner; and 3rd, the initial pressure of the gas. The range of combinations enables one to select a burner to suit almost any description of gas or any standard of pressure. The accompanying table gives the results of tests at 1 inch and 1·5 inch, with 26 candles; the burners are not adapted for lower pressures than 1 inch.

For common gas (*i.e.*, of 14 to 16 candles) a different series of tops is provided, in which the areas are considerably greater than in those made for cannel-gas, and in which the pressure is reduced to from ·1 to ·3 of an inch. These burners cannot be used with cannel-gas, although with common gas they are exceedingly effective and are much in use, especially in London:—

At 1 inch pressure					At 1·5 inch pressure				
No. of Burner	No. of Top	Cubic feet per hour	Illuminating Power	Illuminating Power per 5 cubic feet	No. of Burner	No. of Top	Cubic feet per hour	Illuminating Power	Illuminating Power per 5 cubic feet
2	2	1·2	5·07	24·13	2	2	1·4	5·25	18·75
2	3	1·4	6·64	23·71	2	3	1 95	7·37	18·90
2	4		Smokes		2	4	2·3	10·33	22·46
2	5		Smokes		2	5	2·4	11·24	23·42
2	6		Smokes		2	6		Smokes	
2½	2	1·4	5·53	19·75	2½	2	1·9	8·3	21·84
2½	3	1·7	8·48	24·94	2½	3	2·3	10·14	22·04
2½	4	2·03	10·33	25·49	2½	4	2·7	12 08	22·37
2½	5		Smokes		2½	5	2·85	14 29	25·07
2½	6		Smokes		2½	6	3	15·21	25·35
3	2	1·45	6·27	21·62	3	2	2	8·48	21·20
3	3	1·90	8·66	22·79	3	3	2·4	11·34	23·63
3	4	2·13	11·24	26·39	3	4	2·8	14·84	26·50
3	5		Smokes		3	5	3·15	17·04	27·20
3	6		Smokes		3	6	3·25	18·07	27·80
3½	2	1·5	5·81	19·36	3½	2	2·12	8 85	20·87
3½	3	1·95	8·3	21·28	3½	3	2·55	12·63	24·76
3½	4	2·55	12·08	23·68	3½	4	3	14·47	26·12
3½	5	2·8	14·38	25·68	3½	5	3·5	18·07	25·81
3½	6	3	15·58	25·97	3½	6	3·6	19·45	27·01
4	2	1·6	6·36	19·87	4	2	2·3	9·77	21·24
4	3	2·1	10·69	25·45	4	3	2·9	13·83	23·84
4	4	2·65	13·37	25 23	4	4	3·3	17·06	25·85
4	5	3·45	17·61	25·52	4	5	4·1	21·57	26·30
4	6	3·55	18·07	25·45	4	6	4·2	22·40	26·66
5	2	1·77	7·38	20·85	5	2	2·6	9·68	18·81
5	3	2·3	11·9	25·87	5	3	3·3	13·64	20·67
5	4	3·3	15·4	23·33	5	4	4	19·91	24·14
5	5	4·1	20·74	25·29	5	5	5	25·36	25·36
5	6	4·3	22·68	26·37	5	6	5·3	27·66	26·10

This table shows that it is easy, with properly adjusted batwing burners, to obtain, with a consumption of from 3 to 5 cubic feet per hour, at least the full effect of illumination exhibited in the standard mode of testing already referred to; and that even with a consumption of 2 cubic feet a very favourable result may be obtained. In no case is the loss of light with batwing burners so great as with badly arranged union jets.

Many other descriptions of improved batwings have been constructed, some of which have been tested. The "Clegg" batwing, manufactured by Sugg, has a steatite top and a conical brass body closed at the bottom, and with a slit cut in it with a fine saw. The respective sizes of the slits above and below determine the consumption of gas and the pressure at the point of ignition. In Silber's batwing, made by the Silber Light Company, one burner is placed above another, both being of steatite, the slit of the lower one being much smaller than that of the upper, and con-

nected by a vase of brass. Only the three smallest sizes of these are suitable for rich cannel-gas, the larger ones being intended for gas of lower quality. The following are the results obtained with 26 candle gas :—

CLEGG AND SILBER BATWINGS.

	At ·5 inch pressure			At 1 inch pressure			At 1·5 inch pressure		
	Gas, cubic feet per hour	Illuminating Power	Illuminating Power per 5 cubic feet	Gas, cubic feet per hour	Illuminating Power	Illuminating Power per 5 cubic feet	Gas, cubic feet per hour	Illuminating Power	Illuminating Power per 5 cubic feet
Clegg, No. 2 .	2	9 15	22·87	3 4	14 77	21 72	4·45	18·3	20·56
" " 3 .	2·9	13	22·41	4 45	21 11	23·72	5·7	27·04	23·72
" " 4 .	4 2	20·37	21·25	6 15	31 2	24·19		Blows	
" " 5 .	4 8	23·92	21 92		Blows			Blows	
Silber, A .	95	3·07	16 16	1 5	6 31	21 03	1·9	10·03	26 4
" B .	1·55	7·31	23 68	2 35	12 07	25 68	3	15·04	25·07
" C .	2 2	11·24	25·51	3 3	17 27	26 17	4 25	23·12	27·2

Several varieties of regulating batwings have been invented by Sugg, Witthoft, Winsor, and others; the principle of their construction being to check the flow of gas by means of a plug regulated by a screw. At a given pressure in the pipes the burners may be regulated to deliver any desired quantity of gas; and in the experiments on the Winsor and Sugg burners quoted below, they were regulated so as to burn the number of cubic feet per hour corresponding with the numbers marked on the burners. Gas used = 26 candles :—

Sugg's "Winsor" Batwing				Sugg's "Regulating" Batwing			
No.	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet	No.	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet
2	2	9·6	24	2	2	9·2	23
3	3	15	25	3	3	15·34	25·56
4	4	19·87	24·84	4	4	19·9	24·88
5	5	25·2	25·2	5	5	24·75	24 75
				6	6	28·74	23·95

If two batwing flames are brought together, especially if the slits be narrow, the gas of low quality, and the pressure somewhat high, the illuminating power of the united flame is greatly in excess of the sum of the two tested separately. Upon this principle is constructed a double-slit batwing, the slits being about 1 millimetre apart, which is used in

Manchester and other towns in England, and which is an excellent burner for gas not exceeding 20 candle power, but gives a somewhat smoky flame with gas of high quality.

The only other batwing that requires further to be noticed is the patent regulating batwing used in the United States of America, where it was introduced in 1871, and which is practically the only flat flame burner capable of burning advantageously the "air-gas" made by saturating air with the vapour of petroleum spirit. It consists of a very much elongated iron batwing with an exceedingly narrow slit, surrounded by a brass tube at the distance of about 2 millimetres; into the space between the two, gas is admitted by a wide orifice (the amount being regulated by a screw), and this gas ascends entirely without pressure, while the force of the gas issuing from the narrow slit spreads it out into a fine soft flame. This burner gives excellent results with gas of all qualities, but its shape is not adapted to the gas fittings in use in this country, and it has not been used here except for air-gas made for private houses.

Argand burners are exclusively used in the photometric testing of common gas, and they are also employed rather extensively for lighting shops and public buildings, but to a limited extent for private houses. They give a higher photometric effect with common gas than any flat-flame burner known; and even with cannel-gas, the best descriptions, especially those of Sugg and Silber, give results which approach very near to those obtained when the gas is tested at a comparatively low pressure by large-sized fishtail or batwing burners.

The original form of Argand was a brass double cylinder with, above, an iron ring perforated with small holes, and below, a "crutch" or forked tube, by which the gas was introduced at opposite sides. A wide and short glass chimney was used, but this was afterwards modified in a variety of ways with a view to making the current of air impinge more directly upon the flame and so increase the intensity of combustion. The holes being small, the gas escaped at a comparatively high pressure; and the character of the flame both as to volume, shape, and luminosity, depended partly upon the initial velocity with which the gas escaped from the burner, and partly upon the shape and dimensions of the funnel. The enlargement of the holes enabling the gas to escape at a moderate pressure was proposed by the late Dr. Letheby, who was afterwards associated with Mr. Sugg, by whom many improvements in Argand burners have been introduced. The Letheby burner raised the *apparent* quality of London gas from 12 to 14 candles, and a further increase of 2 candles was obtained by Sugg's London Argand now generally accepted as the standard burner for testing gas made from common coal. In this burner the principle is recognised of permitting the gas to escape practically without pressure, the shape and volume of the flame being determined by the narrow funnel and a "cone" of thin metal which serves to throw the current of air into close contact with the outside of the flame. The upper portion of the burner is of steatite, and instead of the ordinary "crutch" below, the gas is introduced by three very narrow tubes. A number of sizes of this burner are made of which details are given below, but the following are the various dimensions of the standard burner used in photometry:—Diameter of steatite top, external, ·84 inch; internal, ·47 inch; number of holes, 24; diameter of holes ·04 inch, chimney 6 × $1\frac{3}{4}$ inches, for gas of 14 candles, and 6 × 2 for gas of 16 candles. The narrow funnel and the cone restrict the quantity of air to very little more than is required to

burn the gas, thus avoiding the diminution of light which results from a too rapid combustion of the gas, and the cooling effect of a large quantity of air. The pressure of the gas inside the steatite top is considerably less than ·1 of an inch, and that required to pass 5 feet per hour through the complete burner is about ·2 of an inch.

In the burner introduced by Mr. A. M. Silber, the steatite top with wide holes (about 1 millimetre or ·04 inch) is also adopted, but the body of the burner is considerably prolonged, and the so-called "cone" is long and cylindrical with a curved top. A very essential feature in the Silber Argand is an air tube introduced into the centre of the jet, which is said to carry a portion of the air to the upper part of the flame, and which certainly has a remarkable effect in steadying it. The funnel is 7 or 8 $\times 1\frac{3}{4}$ inches, and in consequence of the form of the "cone" is kept so cool at the bottom that it may be handled without difficulty while the flame is burning. Funnels of 10 inches high are also used, but while the consumption of gas is thereby increased, the illuminating power per cubic foot of gas remains almost quite constant. Mr. Silber has recently discovered the remarkable fact that a globe or vase placed below his Argand increases the illuminating power considerably; and his statement has been verified both as to common and cannel gas, the increase with the former being about a candle, and with the latter about $1\frac{1}{2}$ candle. The effect of placing a vase below an ordinary union jet was also tried, but no increase of light was obtained, while the flame showed a distinct tendency to "blow." That the flame of the Argand should have its illuminating power increased 6 per cent. by passing the gas through a glass vase (or cylindrical metal box, which answers the purpose equally well) is a phenomenon which appears to be at present incapable of explanation.

The following table gives the results of photometric tests of various Argand burners with cannel-gas of 26 candles illuminating power. From 3 to 4 cubic feet of gas per hour was burned in each case, and the result calculated to the usual standard of 5 feet per hour:—

	Size of Funnel	Illuminating Power
German porcelain Argand, with cone (40 small holes) ...	$8 \times 1\frac{3}{4}$	17·80
Leoni 40 hole burner, "adamas" top, with cone	$7 \times 1\frac{7}{8}$	18·18
Sugg-Letheby, 15 holes, in steatite ring, perforated gallery	7×2	18·86
American regulating Argand, brass, 40 very large holes ...	5×2	21·03
Sugg's London Argand, 21 holes, with cone and regulator	$7 \times 1\frac{3}{4}$	22·10
Silber 40-hole burner, steatite top, cone, and centre tube...	$8 \times 1\frac{3}{4}$	22·54
Do. 32 do. do. do. do. ...	Do.	23·08
Do. 24 do. do. do. do. ...	Do.	24·01
Do. do. do. with glass vase below	Do.	25·61

The following tests were made with various Argands in order to test the effect produced by the cone and by the centre tube of the Silber burner:—

	Pressure at inlet of Burner	Gas per hour, cubic feet	Illuminating Power	Illuminating Power pr. 5 cubic ft.
Sugg's London Argand, 24 holes	·19 inch	3·3	15 0	22 73
Do. do. without cone		2 6	11·8	22·7
Do. do. older pattern, 36 holes	·17 inch	4·0	16·75	20·94
Do. do. without cone		4·0	17·0	21·25
Silber's 24-hole burner, complete	·05 inch	4 0	19 2	24·00
Do. do. without cone, but with air tube		4 15	19·0	22·89
Do. do. without air tube, but with cone		3·8	17 2	22·63
Do. do. without cone or air tube		3·4	13·1	19·26

These tests show that the cone, by increasing the draught, enables a larger quantity of gas to be burned, an effect which could be obtained equally well by increasing the height of the chimney; and the air tube of the Silber burner also produces a similar effect, increasing at the same time the heat and illuminating power of the flame and its stability. Indeed, the Silber burner without cone and centre tube, and especially when the latter is removed, gives so unsteady a flame that it is practically useless for illumination, while, in its complete condition, it gives the steadiest flame of any Argand yet constructed.

A series of experiments were made in order to ascertain the relative dimensions of the inlet and outlet of various burners. The upper steatite portion of each burner was removed and fitted up in a little bit of apparatus extemporised for the purpose, so that gas could be passed through the holes, while the bottom portions were simply screwed on in the usual manner, and the gas allowed to escape without lighting it. In all the trials the pressure of the gas was maintained steadily at ·2 of an inch of water. The numbers represent cubic feet of gas per hour:—

	Bottom	Top	Complete Burner
Sugg-Letheby 15-hole burner	16·7	28 7	11·6
Sugg 24-hole standard London Argand	4·9	28·8	4·5
Do. 36-hole older pattern	6·1	29·1	6·0
Silber 24-hole	17·7	29·5	17
Do. 40-hole	19·1	28·8	18·7

These results show that the pressure of the gas is checked much more efficiently at the bottom of the burner by Sugg's arrangement than by that of Silber, and in fact the latter has usually attached to it a small regulator adjustable by a screw, without which, and when regulated only by a stopcock, a disagreeable hissing noise is produced by the passage of the gas through the almost closed stopcock.

The "Bec à Bengel," or Bengel Argand burner, used for gas testing in Paris, has a porcelain top, with 30 rather small holes, a brass cone, and at

the bottom what is called a "panier," constructed of porcelain, and pierced with numerous holes for the admission of air. The funnel is $8 \times 1\frac{3}{4}$ inches. With 26 candle gas it burned 2·5 cubic feet, and gave a light of 10·8 candles, or for 5 feet per hour 21·6 candles.

Sugg has constructed a series of "London Argands," burning from 3 to 12 cubic feet per hour of common gas, and from $1\frac{1}{2}$ to $7\frac{1}{2}$ cubic feet of cannel-gas per hour. Those from A to I resemble in every respect the standard London burner already described; K has, in addition, a single or rat-tail jet in the centre, and that marked double is formed of two concentric Argands. They gave the following results:—

Burner	No. of holes.	Funnel	Height of flame	Gas per hour	Illuminating Power	Illuminating Power per 5 cubic feet
A	15	$6 \times 1\frac{5}{8}$	$2\frac{1}{4}$ inches	1·85	7·67	20·73
B	18	Do.	$2\frac{3}{4}$,,	2·65	11·90	22 45
C	21	$6 \times 1\frac{3}{4}$	3 ,,	2·85	12·63	22·16
D	24	$7 \times 1\frac{3}{4}$	3 ,,	3·25	13·74	21·14
E	27	Do.	3 ,,	3·4	14·67	21·57
F	30	Do.	$3\frac{1}{4}$,,	3 72	15·97	21·48
G	33	$8 \times 1\frac{3}{4}$	$3\frac{3}{4}$,,	4·5	19·13	21·25
H	36	9×2	4 ,,	5·05	21·17	20·96
I	40	Do.	4 ,,	5·3	22·3	21·04
K	42	Do.	$4\frac{1}{2}$,,	6·5	28·4	21·84
Double	54—21	$10 \times 2\frac{1}{2}$	6 ,,	7·8	36·4	23·33

It is only right to state that all those burners are constructed to burn common rather than cannel gas. A Silber Argand of 24 holes, with chimney $8 \times 1\frac{3}{4}$ inches, was tested at the same time for comparison, and gave, for a consumption of 3·75 cubic feet per hour, calculated to 5 cubic feet, an illuminating power of 24·02 candles, a somewhat higher result than was obtained with any of Sugg's series, and proving that Silber's Argand is well adapted for burning cannel-gas.

The standard of comparison is a sperm candle burning at the rate of 120 grains per hour, and in practice two candles are used. It is well known to gas examiners that the candle cannot be depended upon to give a constant illumination, so that a series of tests, using candles as the standard of comparison, would be certain to present such irregularities as to be of little value. It would be out of place in this report to refer to the methods proposed by Crookes, Harcourt, and others, for obviating this difficulty by substituting other sources of light; it is sufficient to indicate the system pursued in making the tests with cannel-gas, the results of which have been given. A 100-inch photometer was fitted up with two complete sets of apparatus—each side having its experimental meter, balance, governor, and pressure-gauge. At the right-hand side was the light to be tested, and at the left two small straight or rat-tail jets, occupying the exact position of the candles in the ordinary system of gas testing. These were attached to a bracket hinged so that by the aid of two plumb-lines they could be brought into exact position when required. The Keate's candle balance, which was used for standardising the small gas flames, was removed after a very careful test was made with the candles,

and the gas jets placed in position and accurately adjusted by the governor to exactly two candles. Both meters were placed on the left side, and close together, and were provided with three-way cocks, so that the gas could be turned off or on each meter without disturbing the burning of the gas. In making the test with the candles, these were carefully selected and prepared, and after being lighted were allowed to burn for twenty minutes before the test was proceeded with. The photometer room was large and well ventilated, but absolutely free from sensible currents of air; diaphragms covered with black velvet were placed in well-selected positions, and all surfaces which by any possibility could reflect light were also covered with the same material. After working for some hours the gas was tested again in order to ascertain whether its quality remained constant, and if it had changed sensibly the tests which had been made were rejected.

Experiments were made in order to ascertain the loss of light resulting from the use of globes of different kinds and of various shapes. The loss is always considerable and in many cases excessive, and it results partly from the absorption of light from the material of the globe and partly from the draught caused by the ascension of the heated air in the confined space. As regards material, a piece of clear window-glass held in front of a gas flame diminishes the light to the extent of about 10 per cent., but in the case of a clear globe it is in some cases less owing to the reflection from the surface farthest from the photometer. Globes frosted or ground all over, technically known as "moons," absorb about 25 per cent. of the light when well shaped, and opal or "cornelian" globes 40 to 50 per cent., according to the thickness and quality of the glass. The following results were obtained with globes of different sizes ground all over, and show the effect of increased draught in diminishing the light:—

A 6-inch	globe	caused	a loss	of	25	per cent.
A 7½	"	"	"	"	27½	"
A 10	"	"	"	"	38	"

All these globes had the usual sized opening below - about 1¾ inches in diameter. Experiments were made with clear 7½ inch globes, having openings below varying from 2⅜ inches to 1 inch in diameter. The source of light was a Brönner batwing, No. 5 top, No. 4 bottom, burning under a pressure of 1 inch 3·35 cubic feet of gas.

The naked flame gave a light of 16·8 candles.

With clear globe,	opening below	2⅜	inches,	15·4,	loss	8·3	per cent.
"	"	2¼	"	15·2	"	9·5	"
"	"	2	"	13·6	"	19	"
"	"	1½	"	13·0	"	22·6	"
"	"	1	"	12·0	"	28·6	"

With the two larger sized openings the flame was perfectly steady, with the 2 inch opening there was a slight flickering caused by the draught; this was more marked with the 1½ inch opening and was excessive with the 1 inch opening, making the flame practically useless as a source of light. It is evident, therefore, that the openings of the globes should be as wide as possible, and not less than 2½ inches. The cornelian globes used in Brönner's system of gas lighting have an opening of 2⅜ inches diameter, and Sugg has introduced globes of similar

material, which he calls "albatrine," but with openings of $4\frac{3}{8}$ inches diameter. These globes are constructed of various sizes to suit certain burners, both batwing and Argand, and the combinations are known by certain names, such as the Westminster, Viennese, Frankfort, Italienne, Parisienne, &c. Some of these arrangements are fitted with Argands, and some with batwings, and some have attached to them regulators with the intention of maintaining a constant pressure.

One of the difficulties connected with gas illumination is that the pressure in the mains varies considerably in different parts of a town, and at different hours of the day and night. One result is that a system of lighting adapted for a part of a town situated in a low level will show inferior results in a more elevated situation. A rise of 10 feet gives, roughly, a tenth of an inch of increase of pressure, so that it may easily happen that in the same town or city the pressure in one place may be 1 inch, while in another it may be $2\frac{1}{2}$ inches. Again, the pressure of the gas as sent out from the gaswork is altered from time to time in accordance with the consumption, and as public works, shops, &c., are suddenly lit up or extinguished at certain hours, private consumers are annoyed in the one case by a falling off in the amount of light, and in the other by a flaring flame and hissing sound, both of which are very irritating. The cure for these evils is to be found in the use of governors or regulators. Every district of a town, the elevation of which is such as to affect appreciably the pressure of the gas, should have a governor, which may either be self-acting to maintain a constant pressure throughout the day, or to vary sympathetically with the governor at the gasworks. Many of these have been invented, among which may be mentioned those of Cathels, Peebles, and Foulis. The pressure in the mains should not be reduced below 12 or 14 tenths of an inch; but as over that is too high a pressure for the economical burning of gas, each house should have a regulator in order to reduce the pressure constantly to about 7 or 8 tenths. Some of these regulators are dependent on the action of the gas upon a broad leather disc, attached to which is a ball-and-socket valve, while others have metal or glass bells floating in mercury, and acting upon a valve of the same kind. Both of these work satisfactorily. Among the best dry regulators are those of Sugg of London, and Peebles of Edinburgh, while probably the best mercurial governor is that of Busch of Oldham. In the case of public works, and other buildings consisting of several floors, a regulator should be placed in each floor, and one should be placed on each street lamp, for which a special form is constructed. The best street lamp regulators made in this country are those of Peebles and Sugg, but a very admirable little instrument called a rheometer is extensively used in Paris, and has been tried with tolerably successful results in several of our own cities. It is the invention of M. Giraud of Paris, and it differs from the regulators which maintain a constant pressure in delivering a constant volume of gas, with any size of burner, and under any pressure, provided that the pressure is not less than 7 or 8 tenths of an inch, and the burner is sufficiently large to pass the requisite quantity of gas. The recently invented "needle governor" of Peebles is similar in principle, and maintains a given volume of gas with remarkable constancy.

Fourteenth Report of the Committee for Exploring Kent's Cavern, Devonshire—the Committee consisting of JOHN EVANS, *F.R.S.*, Sir JOHN LUBBOCK, *Bart.*, *F.R.S.*, EDWARD VIVIAN, *M.A.*, GEORGE BUSK, *F.R.S.*, WILLIAM BOYD DAWKINS, *F.R.S.*, WILLIAM AYSHFORD SANFORD, *F.G.S.*, JOHN EDWARD LEE, *F.G.S.*, *and* WILLIAM PENGELLY, *F.R.S.* (*Reporter*).

THE Thirteenth Report of the Committee, read to the Geological Section of the Association, at Plymouth, in August 1877, brought up the history of the Exploration of Kent's Hole to the end of July of that year. (See 'Report Brit. Assoc.,' 1877, pp. 1–8.) In their present Report the history is continued to the end of July of the current year. During the twelve months thus defined, the work has been carried on without intermission; it has been conducted and superintended in all respects as in former years; the workmen—George Smerdon and William Matthews—named in 1877 are still engaged on the investigation; and the public, who continue to visit the Cavern in large numbers, have been admitted under the regulations described in former Reports.

On the day following the close of the meeting of the Association in 1877, a large number of the Members and Associates were conducted into the Cavern by one of the Superintendents, who, on the spot, described the principal facts which had been discovered; and on the 25th of the following month the same Superintendent had the pleasure of receiving the members of the Teign Naturalists' Field Club, on the occasion of their holding one of their meetings there.

The following may be mentioned amongst the numerous other visitors who have been accompanied by the Superintendents:—The Duke of Somerset; Lord Justice Bramwell; Sir S. W. Baker; Revs. Prebendary R. R. Wolfe, W. Gregor, R. E. Lomax, and J. F. Mitchell; Professors J. H. Gladstone, H. D. Garrison (Chicago), and A. Thomson (Pres. Brit. Assoc.); Drs. Armstrong, Bell, Boycott, Ogle, and Taylor; and Messrs. W. Aldam, W. W. Aldam, G. T. Bettany, F. W. Blood, E. Broderip, J. R. Byrom, G. Campbell, A. V. Dobson, A. M. Gibson, G. Gladstone, E. H. Griffiths, H. B. Hederstedt, J. E. Howard, A. R. Hunt, P. Jenkins, A. Jessup, F. P. Latham, F. H. Lloyd, F. J. Lowe, T. Luckcraft, G. Macdonald, O. W. Malet, S. S. Marling, C. Martin, H. C. Moffatt, W. Morrison, E. Oldfield, A. Pengelly (Punjab), J. H. Pollard, R. Pollard, W. Pollard, J. Smith, W. J. Sollas, T. E. Stabb, W. W. Stabb, T. S. Stooke, G. H. Storrs, W. H. Storrs, J. M. Thomson, T. Tozer, F. R. Wolfe, J. E. Wolfe, W. Wolfe, and C. W. Wood; and a large number of Ladies.

The Tortuous Gallery.—When their Thirteenth Report was drawn, the Committee were engaged in the exploration of a branch of the Cavern opening out of the southern end of the "Bear's Den," to which, on account of its form, they had given the name of the "Tortuous Gallery." (See 'Report Brit. Assoc.,' 1877, p. 7.) This gallery divides itself into two reaches and a small terminal chamber. The first or outermost reach extends southwards from the Bear's Den about 23 feet, where it is succeeded by the second reach, which, after a course of 11 feet in an easterly direction, reaches the terminal chamber. The reaches vary from 6 to 8 feet from the roof to the bottom of the excavation, and from 1·5 to 4·5

feet in width—the second or innermost being the narrower. The upper surface of the deposits they contained inclined inwards, falling 13·5 feet in the 34 feet between the Bear's Den and the terminal chamber, or at a mean gradient of 1 in 2·5. In the eastern wall of the first reach, about 16 feet from its entrance or northern end, an opening leads to a considerable undervaulting, to be subsequently described; and near the junction of the reaches a small recess extends southwards about 5 feet. At the end of July 1877 the two reaches only had been explored. (See 'Report Brit. Assoc.,' 1877, pp. 7–8.)

On entering the terminal chamber, its floor was found to be a complete pavement of blocks of limestone, some of them of considerable size. Their removal disclosed an almost horizontal bed of the typical Breccia —the most ancient deposit yet found in the cavern—the thickness of which was undetermined. It was excavated to the customary depth of 4 feet, but without reaching its base anywhere. The chamber measured about 30 feet from north to south, from 7 to 13 feet from east to west, and from 8 to 13 feet from the roof to the bottom of the excavation. A narrow gully extended towards S.S.E. from the southern end, but became too contracted for a man to pass beyond 7 feet in that direction. The roof of the chamber was much fretted, and had several vertical and almost cylindrical cavities, about a foot in diameter as well as in height. The walls were very angular, and presented everywhere so much the appearance of fresh fracture as to suggest that the blocks of limestone forming the floor, as already stated, had fallen from them in comparatively recent times.

The only objects of interest found in the chamber were four pieces of bone (Nos. 7093-5), which occurred at depths exceeding a foot, and a lump of oxide of manganese (No. 7092) found in the third foot-level.

The recess, near the junction of the two reaches, as mentioned previously, was in proportion to its capacity much more productive, as it yielded four "finds" (Nos. 7096–9), including 12 teeth of bear and several pieces of bone. One of the finds (No. 7098) occurred in the Crystalline Stalagmite, and the others in the Breccia, at depths exceeding a foot.

The exploration of the Tortuous Gallery was closed on October 30, 1877, after having occupied very nearly 5 months. It yielded a total of 23 "finds," of which 15 were described in the Thirteenth Report. The entire series, from first to last, included 26 teeth of bear several of them in pieces of jaws—1 tooth of horse, several bones and pieces of bone, 3 bits of coarse friable black pottery, and a piece of black flint—in all probability a "strike-light" of the present century. The relic of horse, as well as the potsherds and the strike-light, was found on the surface, and very near the Bear's Den.

The Undervault.—On the completion of the Tortuous Gallery, the exploration of the branch thrown off towards the west, from its first reach, as stated above, was at once undertaken. This has been called the "Undervault," as it was probably the principal "undervaulting" mentioned by Mr. MacEnery in the following passage from his *Cavern Researches* (see 'Trans. Devon. Assoc.,' iii., 307 8):—"In a narrow neck which, on the right hand as you enter, issues from the Bear's Den, you come to a naked floor of rock (see 'Report Brit. Assoc.,' 1877, p. 7) perforated with numerous shafts or spiracles by which you descend, by the

aid of hands and feet, as down a chimney, into a low space. They expand into a low range of undervaultings, extending under the upper cave to a considerable extent, but too low to be accessible to any extent. From the first landing place there is a gradual descent, step by step, into a second and even a third terrace, like so many stories. Broken flags of stalagmite—the debris of the successive formations—were strewed about and partially inserted in the latest crust now actually accumulating. In one place the crust went bodily down entire with the loam it covered; in another it may be seen extending across in the form of a bridge; in more places it was shattered to pieces and reversed."

The observations made by the superintendents of the present exploration harmonise well with Mr. Mac Enery's description just quoted. The deposit found in the Undervault must be regarded as an uncertain mixture of cave-earth and breccia, probably washed confusedly together by water descending rapidly, and at intervals, to the lower levels. The total number of "finds" met with was 35, of which by far the greater number were not more than 2 feet below the surface. They included 47 teeth of bear, 33 of hyæna, and 2 of fox, numerous bones and fragments of bone, 1 chert flake, and the greater portion of a large quartzite pebble. Many of the teeth, of both bear and hyæna, were in jaws or portions of jaws.

Amongst noteworthy specimens may be mentioned the right lower jaw of a hyæna (No. 7101), which contains all the teeth with the exception of two of the incisors, the outer and inner, and is almost perfect; whereas most of the jaws of the hyænine deposits in Kent's Hole are more or less mutilated, having lost the condyles, or the lower border, or both. It was found within a foot of the surface, with 1 tooth of bear, a vertebra of the same hue as the jaw, and several bone chips, on November 3, 1877.

No. 7129, also a right lower jaw of hyæna, and a fine specimen, has lost its condyles and all the incisors, but is otherwise perfect. The teeth, however, have seen more service than those in the jaw described previously. It was found with 4 detached teeth of hyæna, and several bones, in the second foot-level, on November 4, 1877.

In striking contrast to the two foregoing specimens is a portion of a left lower jaw of hyæna (No. 7131), which, whilst it retains all the molar teeth, has lost its condyles and lower border, and is thus in a condition much more characteristic of the Cavern. It was found, with a canine tooth of fox and several bones, in the first foot-level on November 7, 1877.

The "find" No. 7234 included part of the left lower jaw of bear, containing the canine and 2 molar teeth, and a detached tooth of bear; and was found in the second foot-level on December 11, 1877. This was the last "find" met with in the Undervault.

The chert flake (No. 7102) is of a dark grey colour, has a pentagonal outline, and was in all probability produced artificially. It was found, with a canine tooth of fox and pieces of bone, in the first foot-level, on November 3, 1877.

The fragment of a quartzite pebble mentioned above (No. 7119) is more than half of a well-rounded ellipsoidal mass, weighing nearly 3 lbs. avoir. It was met with in the second foot-level, without any object of interest near it, on November 19, 1877; and does not bear any traces of having been used as a "hammer stone." The exploration of the Undervault ended on December 17, 1877.

The Great Oven.—The narrow branch of the Cavern connecting the Cave of Inscriptions with the Bear's Den, by passing from the southern side of the former to the north-western corner of the Den, is known as the "Great Oven." It consists of three reaches—the western, opening out of the Cave of Inscriptions; the central; and the eastern, opening out of the Bear's Den. They are all, and especially the central reach, very contracted in both height and width. The western reach was explored in 1875 (see 'Report Brit. Assoc.' for 1876, pp. 2–3), the central one does not appear to have ever contained deposits of any kind, and the eastern reach occupied the Committee from December 18, 1877, to February 15, 1878.

At its junction with the Bear's Den, the eastern reach had a continuous unfractured floor of stalagmite of great thickness, and, with the exception of a thin upper layer, all belonging to the Crystalline or most ancient variety; whilst at the southern angle was a boss of the same material fully 5 feet high. Beneath this floor lay the deposit termed the Breccia; but at 6 feet from the entrance, and thence onward, Cave-earth presented itself between the two stalagmites. At first it was found adjacent to the northern wall only, and in a depression in the surface of the Crystalline Stalagmite, but it soon extended itself from wall to wall, and for a few feet the successive sections were in descending order.

1. Granular stalagmite, a few inches thick only.
2. Cave-earth, also but a few inches thick.
3. Crystalline stalagmite, from 2 to 3 feet thick.
4. Breccia, the base of which was nowhere reached.

At about 10 feet from the entrance the lowest two deposits occupied so narrow a slit that all attempts to excavate them were abandoned; and from that point to the inner end of the reach, the Granular Stalagmite varied from 6 to 12 inches in thickness, and the Cave-earth from 6 to 24 inches.

The length of this reach of the Great Oven was 34 feet, and its width varied from 10 feet at the outer to 3 feet at the inner end. It may be described as a narrow oblique slit in the limestone.

It yielded a total of 29 "finds," 2 of them in the Granular or least ancient Stalagmite, 16 in the Cave-earth, 2 in the Crystalline Stalagmite, and 9 in the Breccia. The animal remains included 36 teeth of bear—of which 20 were in the Cave-earth, 1 in the Crystalline Stalagmite, and 15 in the Breccia—8 of hyæna, and 3 of fox. The only relics found in the Breccia were those of bear. The presence of the hyæna was also attested by a few coprolites in the Cave-earth.

The only noteworthy "find," perhaps, was No. 7138, which included an almost perfect left lower jaw of hyæna, 2 detached teeth of hyæna; 5 teeth of bear; a few bones, including a perfect left radius; pieces of bone; and a few coprolites. This "find" was met with in the first foot-level, in the cave-earth, on January 30, 1878.

A total of 40 "finds" was met with in the two reaches of the Oven, in 1875 and 1878 together; 2 of them were in the Granular Stalagmite, 18 in the Cave-earth, 2 in the Crystalline Stalagmite, and 18 in the Breccia. The relics in the Cave-earth included 20 teeth of bear, 9 of hyæna, and 3 of fox, whilst those of the Crystalline Stalagmite and the Breccia included 25 teeth of bear.

Nothing indicating the presence of man was detected in any part of the Great Oven.

The High Chamber.—In their Eleventh Report (1875) the Committee stated that on June 15, 1875, they commenced the exploration of a "Recess," opening out of the north-west corner of the Cave of Inscriptions, which it was expected would lead to a new external opening to the Cavern; that its floor, a sheet of Crystalline Stalagmite, abruptly truncated at the junction of the recess and the Cave of Inscriptions, had been found, by boring, to be 18 inches thick; that this floor covered and rested on a thick accumulation of Breccia, reaching a higher level than elsewhere in the Cavern so far as was known; that it had been intended to leave the floor intact, and to burrow under it; that at 10 feet from the entrance the lateral walls were so very nearly together as to render it necessary to abandon the work altogether, or to break up the floor so as to secure, at a higher level, sufficient space for the operations of the excavators; and that the work had been reluctantly suspended on July 6, 1875, after no more than three weeks had been spent on the recess. (See 'Report Brit. Assoc.,' 1875, p. 11.)

The workmen, on completing the Great Oven, were directed to return to the Recess just mentioned, and, in accordance with the conclusion arrived at in 1875, as already stated, to break up the thick floor of stalagmite, instead of attempting to burrow under it. From that time they have been exclusively occupied there, and at the end of July, 1878, had advanced upwards of 30 feet from the entrance, and reached a level of about 6 feet above that of the adjacent Cave of Inscriptions. On account of this comparatively high level, the name of the "High Chamber" has been given to the so-called Recess.

From the entrance up to 25 feet within it, there was a continuous unbroken floor of stalagmite from 5 to 6 feet thick, with several large bosses of the same material rising from it; but everywhere beyond, so far as the work has at present advanced, the floor consisted of large blocks of limestone fallen from the roof, and extending almost from wall to wall, but with stalagmite in some of the vertical spaces between them.

The stalagmitic floor consisted mainly of the more ancient, or Crystalline, variety, covered with a thin sheet of the less ancient, or Granular, kind. In most cases the two stalagmites lay one immediately on the other, but a few instances of "pockets," occupied with some Cave-earth, were met with between them; and the Breccia—or, so far as is known, the most ancient deposit in the Cavern—was found everywhere beneath, and in contact with the Crystalline Stalagmite. Large fallen blocks of limestone occurred abundantly in this lowest accumulation, many of them requiring to be blasted before they could be removed; whilst several others, penetrating into the deposit below the depth to which the excavation was carried, were left undisturbed.

From the time the work was resumed in the high chamber up to the end of July, 1878, a total of 53 "finds" had been met with, of which 2 occurred in the Granular Stalagmite, 1 in the Cave-earth, and 50 in the Breccia. Of those in the Granular Stalagmite (Nos. 7153 and 7170), the former consisted of three specimens of black, perhaps charred, bone; whilst No. 7170 was the greater part of an ulna unfortunately broken by the workman who extracted it. The "find" in the Cave-earth, No. 7193, was a solitary molar tooth of a horse.

The specimens yielded by the Breccia included 89 teeth of bear, many of them in jaws or portions of jaws; pieces of skulls, bones and pieces of bone, one flint *nodule* tool, two flint flakes, and a quartzite pebble.

Several of the osseous remains are good specimens, but none of them require detailed description.

The flint implement (No. 7167) was found, without any object of interest near it, on May 16, 1878, in the fourth or lowest foot-level. It is about 3·1 inches long, 2·5 inches in greatest breadth, and 2·2 inches in greatest thickness. It is rounded, but by no means smooth, at one end, where the original surface of the nodule remains; and is abruptly truncated at the other, where its edge is smooth, almost a plane, and measures 1·6 inch by ·5 inch. The prevalent colour is slightly pink, as is usual with the Breccia implements; but the truncated edge, already mentioned, is almost white, and suggested that it was, perhaps, fractured by the workman who extracted it. This, however, he asserts was not the case; and, from the frankness which has always characterised him, the assertion is no doubt correct. The implement is very convex and irregular on each face, whence several flakes have been dislodged. It possesses the rude, massive, unsymmetrical characters which mark the Breccia series of tools.

The flake (No. 7189) is not of much importance. In form it is not unlike an elm leaf; and, though no doubt artificially dislodged from a nodule, it was probably never intended to be used as a tool. It is 2·25 inches long, 1·5 inch in greatest breadth, and ·4 inch in greatest thickness. Its entire edge is thin, and it seems neither to have been used by man nor to have undergone any natural abrasion. It was found in the third foot-level, without any object of interest very near it, on June 11, 1878.

The flake, or, perhaps, fragment of a tool (No. 7203), is 1·5 inch long, 1·2 inch in greatest breadth, and ·6 inch in greatest thickness. It is rudely triangular in form, obliquely truncated at the base where it is broadest, convex on one face, and somewhat flat, but by no means plane on the other. Several distinct facets occur on each face, and especially on the convex one; and its general appearance suggests that it is probably a fragment of a larger tool. It was found alone in the third foot-level on July 27, 1878; but at 2 feet higher level a portion of jaw of bear, containing one tooth, with a few fragments of bone, were found vertically above it the day before.

The quartzite pebble, a rolled fragment of a larger one, is an oblique semi-ellipsoid, measuring 3·3 × 2·2 × 2·2 inches, and, though of a form and size suitable for a "hammer-stone," bears no marks of having been utilised in any way. It was found alone in the fourth foot-level on July 29, 1878.

It is, perhaps, worthy of remark that, whilst the Breccia in the High Chamber has yielded fifty "finds," the "tools," which form three of them, have never been found with any relic of an animal, and have, on the whole, occupied a decidedly lower zone. Thus of the 46 osseous "finds" 31 occurred in the first or uppermost foot-level, 11 in the second, 3 in the third, and 1 in the fourth or lowest, whilst the 3 flints have been found only in the third and fourth foot-levels.

It is difficult to understand how the tools found their way to a branch of the Cavern so remote from the known entrances, and occupying so high a level. The problem is apparently insoluble except on the hypothesis that the workmen are approaching an entrance hitherto unknown; and as this supposition has been forced on the minds of the Superintendents by other and independent facts, they believe it to be most desirable to settle this question if possible, as they do not doubt that it would give a definiteness to the explication of some of the Cavern phenomena.

Report of Committee, consisting of Professor HARKNESS *and* Mr. WILLIAM JOLLY (*H. M. Inspector of Schools*), *reappointed for the purpose of investigating the Fossils in the North-west Highlands of Scotland. By* Mr. JOLLY, *Secretary.*

AT last year's meeting of the Association at Plymouth, the old Committee was reappointed for the discovery of fossils in remote parts of the North-west Highlands of Scotland. One of the most active members of the Committee, and of this Association, the well-known Dr. James Bryce, who had given special attention to the problem of the nature and succession of the rocks of the North-west Highlands, and had frequently studied it on the spot, has perished since last Report, in the prosecution of his favourite science, at Inverfarigaig, near the Falls of Foyers, on the shores of Loch Ness, a loss to science and to friendship.

For several years the Committee have carried on diggings at various points along the great limestone strike that runs from Durness and Loch Eribol, near Cape Wrath, to Loch Kishorn, opposite Skye. These were made chiefly by various local parties resident in the district and interested in the subject, by Dr. Bryce, and by the Secretary, whose official duties as Inspector of Schools have given him unwonted opportunities for this purpose. The fossils discovered were obtained almost entirely in the Durness Limestone, an isolated basin on the Kyle of Durness, fourteen miles east of Cape Wrath. The only other place where fossils have been found in the limestone is at Inchnadamph, on Loch Assynt, in the west of Sutherland. These consist of a single fragment of Orthoceratite, discovered many years ago by the lynx-eyed Mr. Peach, and spoken of in Sir Roderick Murchison's valuable paper on these rocks; and another piece, found by the Secretary, which may turn out to be organic, and which is sent for examination to the present meeting of the Association.

The purpose for which the Committee was originally appointed was to obtain as many fossils as possible from this limestone and its associated rocks, in order that a more decided determination of the kind and age of the fossils might be made, than was possible when Mr. Salter wrote his monograph on the few fragmentary specimens discovered by Mr. Peach in the Durness limestone, and submitted to him for examination. The Committee, after working for some years, succeeded in obtaining a considerable collection of fossils mostly from the same limestone. These were placed under Dr. Bryce's care, and remained with him until his sudden death. Unfortunately, however, on account of his unexpected decease, his collection of fossils was left in a more or less scattered and unmarked state, and though careful search has been made in his house, the Durness specimens have not yet been found. The Secretary has also corresponded with several of his scientific friends on the subject, and with the Jermyn Street Museum, with no better success. Mr. Ralph Tate, to whom it was known Dr. Bryce purposed submitting them, is now in Australia, and could not be communicated with in time for the present meeting. It is sincerely to be hoped that the loss of these fossils is not irretrievable, but that further search will be successful. This will be made in all possible quarters, and the Secretary trusts to be able to report their discovery to the next meeting of the Association.

During the past year, through the good offices of several local friends, particularly the Rev. W. C. M. Grant, the minister of Durness, who has all along taken the most intelligent interest in the subject, and given

the Committee ready and efficient assistance, a considerable collection of fossils has been made, which are now submitted for inspection to the present meeting. These were obtained from an isolated, steep, rocky islet, called Garveilan, or the Rough Island, a few miles east of Cape Wrath. This island is a bare uninhabited rock, the home of the sea-gull and his associates, which is composed entirely of the Durness limestone. It is full of fossils, which appear protruding from the weathered surfaces of the rock, the hard but less indurated matrix enclosing them having yielded to the action of the wild weather and the wilder waves of that iron-bound coast. The fossils are so imbedded in the crystalline limestone on the level surfaces, that they can be abstracted only with the greatest difficulty. Hence many of those obtained were got out only in fragments; but the fossils sent, considering the whole circumstances, are numerous and in singularly good condition. The specimens are mostly of the smaller kinds, the larger not being now obtainable, or having been carried off on previous visits.

The island is very difficult of access, and can be approached only in the very calmest weather. On one occasion, the late Dr. Bryce and the Secretary sailed, with some friends, to the island for the purpose of obtaining fossils, but though the day was calm and the sea unbroken, the great Atlantic swell sweeping round Cape Wrath, which rose against the steep sides of the rock, entirely prevented landing, though anxiously attempted; and the Rev. Mr. Grant and party, in obtaining the fossils now submitted, narrowly escaped with their lives, the great thunderstorm of June last having overtaken them on their return voyage.

Mr. Grant has learned from the boatmen that accompanied him that there is another place, on a cape on the mainland, near Durness, containing good fossils. This he purposes visiting, if he has not already done so; but the Secretary has not yet received any fossils from the Durness limestone, besides those sent.

Some miles east of the Kyle of Durness lies the sea firth called Loch Eribol, on the shores of which there is a great development of the same or a similar limestone, with its associated quarzites and fucoid beds. These rocks give to Loch Eribol its special character of wildness and picturesqueness. The limestone has been worked, for commercial purposes, at Heilim Inn, on its east shore, where the ferry crosses the loch; but, though diligent search has been made on the spot, on many occasions, by members of the Committee and by local and other parties, no fossil remains have yet been discovered in that rock. In the thin, brown, shaly strata, called the Fucoid Beds from their contents, very distinct and well-preserved impressions of sea-plants are abundant on Loch Eribol, and along the great limestone strike from north to south. In the thicker-bedded Quartzite which occurs along this strike in immense masses, forming some of the highest mountains, and giving rise to some of the most striking scenery on the North-west coast of Scotland, with its pronounced features of combined grandeur, mass, wildness, and beauty, the only evidences of ancient life hitherto found are certain worm or annelid borings, more or less abundant everywhere, which are very distinct, having been, in most cases, filled up with different-coloured matter. Both of these proofs of organic life in the past have been spoken of and pictured, in the excellent joint paper on these rocks by Sir R. Murchison and Professor Geikie.

During this year, however, a discovery has been made in this Quartzite, in the shape of certain fossil remains which have not yet been described,

and which may turn out to be of importance. This was made by Mr. Donald Mackay (innkeeper at Portnacon, or the Dog's Port, at the western side of the ferry over Loch Eribol), an intelligent man, with sharp eyes, which he has used to some purpose. On making his discovery, Mr. Mackay communicated with Professor Nicol of Aberdeen, whose valuable paper on these controverted rocks represents one of the two great solutions of the problem of these north-west strata, the other being Sir Roderick Murchison's. Mr. Mackay also sent to Professor Nicol specimens of the new fossils, which are now in his possession. Since finding these first fossils, the discoverer has also succeeded in obtaining others, which he has sent to the Secretary. Unfortunately, the Secretary, who writes the present report in the Outer Hebrides, had to leave home on official duties before the fossils arrived, and has, therefore, had no opportunity of examining them. He has, however, forwarded them to the present meeting for inspection, that they may speak for themselves, Mr. Mackay reserving the ownership of the largest slab for himself. It would be well to have these fossils carefully examined and reported on for the Association, before returning them to their discoverer, in order to determine their nature, and ascertain their bearing on the general problem of the place and succession of the rocks of the North-west Highlands. The specimens in Professor Nicol's possession should also be examined along with them.

In view of the present loss of the fossils once in Dr. Bryce's possession, of the successful search for fossils now being carried on at Garveilan and at the new point already mentioned near Cape Wrath, and of the importance of the discovery of new fossils in the Quartzite of Loch Eribol; it would be most desirable that the Committee should be continued, with a grant at their disposal as hitherto, in order to prosecute the search at Durness and Loch Eribol, and at other points along the great limestone strike. The fact that fossils have been discovered in Loch Assynt shows that diligent search may be crowned with success, there and elsewhere in these interesting rocks.

It is also most desirable that all the fossils discovered in these regions should be submitted to experts, in order that a full report may be obtained in regard to them, so as to have as correct and decided a determination of their character and age as is possible with the new discoveries placed at our disposal. The materials available for this purpose are those: (1) The fossils from the Durness limestone reported on by Salter for Sir Roderick Murchison, and since deposited in the Jermyn Street Museum; (2) those in the hands of the Committee, obtained from Durness, Loch Eribol, and Loch Assynt; (3) those placed under Dr. Bryce's care, which it is hoped may yet be found; (4) a suite of Durness fossils in the Museum of Aberdeen University, gathered for Professor Nicol, and those sent to him from Eribol by Mr. Mackay; (5) others that future search may reveal.

Such a Report would sum up the labours of the Committee, and would, no doubt, be a valuable contribution to Scotch geology.

Fifth Report of a Committee, consisting of Professor A. S. HERSCHEL, *M.A., F.R.A.S., and* G. A. LEBOUR, *F.G.S., on Experiments to determine the Thermal Conductivities of certain Rocks, showing especially the Geological Aspects of the Investigation.*

THE best means used for determining the thermal conductivities of substances are of two distinct descriptions, which may be denoted severally as direct and indirect methods of procedure. In methods of the former kind which were principally used by Péclet, and to which this Committee has had recourse, the rate of passage of heat through the trial substance is measured by the change of temperature of a standard body which it leaves or enters, while the temperature of the trial substance itself is practically free from alteration. In methods of the indirect kind the measure of the quantity of heat which passes is given by changes of temperature of the trial substance itself, and a knowledge of the thermal capacity of the substance per unit of volume is therefore necessary for their application. These latter methods commend themselves not only by a larger choice of conditions most favourable for exact observation which they offer, but also by the absence of any discontinuity in the materials through which the passage of the heat takes place, and consequently of any uncertainty about the area of surface which enters into conducting contact where two solid bodies are placed or pressed together as perfectly as possible. The Committee has indeed found that a film of water wetting two such surfaces completely, and uniting them, renders the whole of their areas effective in conducting heat without introducing any sensible resistance, and fine wires of a thermopile lodged in this water stratum measure the two extreme temperatures of a trial layer of the substance to be tested with the greatest certainty and convenience; but the application of water to porous and to soluble bodies like chalk and rock-salt gives for obvious reasons doubtful values of their conductivities, and only those bodies which resist, and which do not absorb water can be tested accurately for thermal conductivity by those means.* It has therefore appeared very desirable to the Committee, for the successful use of processes in which the indirect method is adopted, to determine as exactly as possible the specific gravities and specific heats of the series of rock-specimens now at their disposal; and in the table presented with this report the results of their observations of these quantities are given of every plate which has hitherto been prepared for their examination. The measurements have been made at their request by Mr. J. T. Dunn,† whose name as a careful and active prosecutor of these investigations the Committee desires, in the event of its reappointment for another year, to add to the rather restricted number of its present members. A brief description of the process of these observations will explain the results of the measurements obtained from them, the statements of which, in a very abridged form, are presented in the table.

* As a means of excluding water without breach of its intimate contact with soluble or porous rock surfaces, it has been suggested to the Committee to "silver" the plate-surfaces with mercury and tinfoil in the same manner that the face of a plate-glass mirror is silvered; and there appears every reason to expect that the coating of amalgam thus applied, while impervious to water would firmly attach itself to and fill up quite solidly all the asperities of the surface; but the actual efficacy of this method for some of the very porous rocks has not yet been practically tested.

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The mean diameter and thickness of each rock-plate was ascertained by callipers applied with the help of a magnifying glass to a standard steel scale of inches divided into tenths and fiftieths of an inch. The volume was thus obtained in cubic inches with a probable error which on account of the small thickness (about half an inch) and its occasional unevenness, together with some irregularity, occasionally, in the diameter of the nearly circular plates, it would be fair to reckon at between a half and one per cent. The rock-plate was then weighed in its state of natural dryness in the atmosphere,* and its specific gravity in the dry state was then deduced by comparison with its water-weight, at 253 grains of water (at maximum density) to a cubic inch. The plate was then heated fourteen or fifteen minutes in boiling water, and quickly transferred to a well-jacketed calorimeter containing (inclusive of its own water-equivalent of 1500 grains) a charge of 15,000 grains of cold water, in which, with the assistance of an agitator (enclosing the indicating thermometer), it was allowed to disengage its heat. The time taken by the plates to impart to the water in the calorimeter its highest temperature varied considerably, from two or three minutes with rock-salt to about twenty-five minutes with pit-coal, with the different plates, and a rough control of the relative conductivities of the various specimens, already previously determined, presented itself accordingly during these immersions. The calorimeter was freshly supplied with water a little colder than the room for each experiment, and it was besides so thoroughly protected by coverings of cork and vulcanised india rubber from outward influence that no correction for heat-loss by radiation was required to be applied. The lumps of rock-salt were thinly painted with wet oil-paint, folded in tin-foil similarly painted inside, and thus rendered waterproof, and were heated (as were also the plates of chalk, plaster of Paris, and two plates of brick) in a well-jacketed steam space until they acquired its temperature, before immersion in the calorimeter. The experiments with brick were conducted to determine the proportion of boiling hot water which porous rocks imbibe by steaming, and by boiling them before plunging into cold water, as the heat conveyed by this water to the calorimeter must be known and deducted before assigning to the dry rock its real specific heat.

After removal from the cold water of the calorimeter each rock specimen was weighed, and being regarded as now perfectly saturated with water, the specific gravity of the rock in its thoroughly wet state was thence obtained, which is given with parentheses, for the porous rocks, in the table. A slight gain of weight was almost always observable, but where this did not amount to one-half per cent., the small amount of porosity which it denotes is regarded as without influence in distinguishing the properties of the wet from those of the dry rock, and only single values of the specific gravities and specific heats of these rocks are noted in the table. It is to be remarked that the percentage gain of weight of the absorbed water must, in order to afford the porosity of the rock as the percentage *volume* of pores or cavities which it contains, be multiplied by the specific gravity of the dry rock (which is *the bulkiness* which water has in comparison with the rock), and the result will be the

* A sensible proportion, perhaps 10 or 12 per cent. of the possible quantity of water absorbable by a porous rock, adheres to it when left to find its own condition of dryness in the open air; and no experiments on rocks artificially dried and freed from this hygroscopic moisture in a water-bath have been attempted, but the "dry" state recorded in the table is the nearly constant condition which the rock naturally assumes in the atmosphere of a well-ventilated room.

space which the absorbed water occupies in proportion, per cent., to the whole volume of the rock, or the porosity as a fraction of that volume. Some special deportment of the water in the rock-pores may, however, sometimes interfere with such a calculation, so as not to allow the real volume of the spaces open to its penetration to be thus determined. It was thus observed that the addition of water to dry sand contracts, and of water to dry clay expands its volume considerably, so that the percentage gain of specific gravity of these substances (dry sand and dry clay) by water saturation, is not the same as their percentage weight of imbibed or appropriated water. Two numbers are given for these substances in the column of percentage gain, the last of which, in brackets, denotes the water added, while to obtain the first or the change of the specific gravity, a new measure of the altered volume of the wet compound material made by the mixture had to be obtained.

The several experiments of heating brick plates in steam and boiling water, without afterwards immersing them in cold water, showed that a single such treatment impregnated the plate with about a half, or upwards, of the whole quantity of water which the plate finally absorbs by plunging it in cold water, and although the same experiments have not yet been extended to other porous rocks, a provisional assumption is adopted for them all, to calculate the specific heats, that the rocks which sensibly absorbed water in the process were laden *with one half of it* at the boiling temperature, when they were plunged into the calorimeter. It is not possible to say if this allowance is too great or too small in any given case, but any rectification which it requires cannot at least exceed (positively or negatively) the adopted value itself, and the percentage change in the calculated specific heats, which a *plus* or *minus* rectification to the whole extent of the adopted allowance would introduce, is subjoined in the column of the table immediately following the specific heats, wherever the capacity of absorption of a rock specimen was so great as to render needful a distinction between its properties in the wet and dry condition. If the allowance of one half of the final water-gain, supposed to be introduced by boiling, is deficient, so that any fractional increase, *or positive* rectification of it is actually required, the same fraction of the percentage correction given in the table must *be subtracted* from each of the specific heats recorded as the provisional observed values in the table. If the allowance was in any case too great by a known part or fraction of itself, and therefore required *a negative* rectification to the extent of such a fraction, the same fraction of the percentage correction in the table is *to be added* to the recorded values of all the different specific heats to obtain their real values. The adopted allowance is probably very near the truth for the slightly porous rocks (whose coefficient of absorption is less than 6 per cent.), and no corrections of the specific heats given in the table are required for these, nor for any of the perfectly compact and solid kinds of rock in which no sensible signs of porosity and of water absorption were observed. With the increase of porosity, however, the assumed allowance probably requires an increasing addition of perhaps nearly its full value for some of the most porous ones (as chalk and plaster of Paris); but considering the smallness of the correction itself in the rocks of small and moderate absorbing powers, a common rule of adding half its value to the adopted allowance, and therefore of subtracting half the percentage amount named in the table from the recorded specific heats of all the porous rocks, is one whose results will certainly not deviate far (it may be five or six per cent. in the most absorbent

rocks), from their real thermal capacities in the wet and dry states, by volume and by weight.

Percentage corrections thus *deducted* from the specific heats by volume of porous rocks in the table, must *be added*, however, (and *vice versâ*) to the value of the ratio $\frac{k}{c}$ given in its last column. The specific heats of dry and wet sand were found by enclosing them hermetically in a thin flask, and are free from any such source of uncertainty as that described; while the amount of water present in the heated clay and in two specimens of brick was known, and the real allowances having been made for these, the specific heats assigned to them in the table need not be corrected. The following examples of the correction when it seems to be required will illustrate its use in other cases.

The average specific heat by volume of three specimens of Calton Hill trap rock (taken from the escarpment of rock on the west side of the Observatory) is 0·52* ; the average *percentage limit* of correction to this quantity is $3\frac{1}{3}$ per cent. Taking a half as a probable fraction of it (or $0{\cdot}01\dot{6} \times 0{\cdot}52 = \frac{1}{60} \times {\cdot}52 = {\cdot}009$) and *subtracting* it from the provisional value, the corrected specific heat by volume of the Calton Hill trap rock is 0·511; or 0·51 instead of 0·52 as presented in the table. The average value of the quantity $\frac{k}{c}$ for the same specimens is 0·0060, in the Table, and the rate of correction which this requires will be the same as that just used ($\frac{1}{60}$), for the specific heat, but *to be added* instead of subtracted from it, with the result 0·0061 instead of 0·0060 taken from the table. The value of the same ratio calculated by Sir W. Thomson from the underground thermometer observations was 0·00786; and adopting for this rock's specific heat by volume the value 0·524, which agrees very closely with the value 0·511 here arrived at, he deduced a value of the thermal conductivity of 0·00415, rather higher than the mean, 0·00312, of the values here concluded by the application of the direct method of experiments.

The average specific heat by volume of six specimens of Craigleith sandstone, four of which are from the site of the thermometer borehole which was established there† by Professor Forbes in the year 1837, is

* Two additional places of figures to which the observations and calculations for the table originally extended are suppressed in this abridgment of its determinations in order to present them together in an easily apprehended view, where it is believed that very little material utility of the individual results is sacrificed by rejecting the last two figures obtained by the reductions.

† The quarry was visited on March 17th, 1878, under the direction of Mr. Wedderburn from Messrs. Adie & Sons, and of Mr. Wallace from the Edinburgh Royal Observatory, by Professor Herschel; the foreman of the present tenant (Mr. Hunter, of Newcastle) soon communicating the object of his search to the best possible authority at the quarry, one of the oldest workmen there, Robert Buchanan, who assisted in sinking the hole, and in depositing the thermometers in it in January, 1837. The face of the quarry in that neighbourhood has not been altered, although the field between it and the tenant's house of Craigleith-Hill, in which the hole was sunk to a depth of 24 feet, was opened over nearly the whole area near the house to a depth of about 20 feet to seek for "Liver rock" (the finest stone of the quarry) in the immedia e neighbourhood of the tenant's house. But the search was unavailing. Robert Buchanan was Mr. Johnson's foreman when the ground was thus turned over and the thermometers were taken up; and he directed the excavations. He selected for Professor Herschel from the face of the quarry near their site several specimens of the rock coinciding as nearly as possible with the top and bottom beds of the sandstone, through which the thermometer hole must have passed. Four plates cut from these specimens are named T 1, 2, and B 1, 2 in the table; and two more plates of ordinary samples of the quarry stone, "Liver rock," a uniform stone without clefts or partings,

0·405; and half the average *limit* of correction which it may require is $7\frac{1}{4}$ per cent., making a part of the whole quantity equal to 0·029. Subtracting this presumptive correction from the whole mean value, the resulting specific heat is 0·376, instead of 0·405 as obtained directly from the table.* The average value of the ratio $\frac{k}{c}$ for the six specimens, 0·01947, corrected *by addition to it* of the same proportional quantity, or $7\frac{1}{4}$ per cent., is 0·02088. Sir W. Thomson's determination of the same ratio's value by reduction of the thermometer records, is 0·02311, 11 per cent. *greater* than the value given by these direct experiments. But the agreement is yet very noteworthy if we reflect that (with the single exception of rocksalt, 0·0288) no other description of rock in the present list exhibits such a high average value of the ratio $\frac{k}{c}$ as Craigleith sandstone; quartz itself being a little inferior to it. It owes this property partly to its *high conductivity*, which in the slightly wetted state that the process entails (averaging in the actual experiments less than 3 per cent., or less than half the quantity of water needed to thoroughly saturate the stone) almost attains that of quartz; and partly to its low heat capacity by volume arising from a specific gravity much less than that of quartz, which it enjoys in common with other building sandstones.

Using for the specific heat by volume of Craigleith sandstone a value, 0·4625, which somewhat exceeds the above found average thermal capacity of the rock, Sir W. Thomson's deduction of its absolute thermal conductivity (from the high value of its ratio $\frac{k}{c}$ already found by his reductions) is also higher, 0·01068, for this second reason, than anything which the Committee has yet met with among rocks of the ordinarily occurring kinds. It must, however, be acknowledged that in its thermal conductivity this building sandstone ranks so high that only compact quartz surpasses it, as the following series of measurements, made during the past year with the apparatus in the excellent state of permanent efficiency which it acquired last year (by the use of German silver and iridio-platinum wires), very plainly indicate.

As a check upon the exactness of the measures of the thermal capacities the annexed table will also supply useful comparisons with some well-known standard observations of these quantities for a few minerals

much used for buildings, and "Bed rock," the more general produce of the quarry, better suited for foundations, were also made from specimens obtained for the Committee from the quarry, before Professor Herschel's visit to it, by Mr. R. Irvine, of Granton. Two tenants of the quarry, before Mr. Hunter's succession to it, have occupied Craigleith-Hill House, and have vacated it since Mr. Johnson's residence there, and the thermometer hole, or well, seems to have been demolished not long after the four or five years' records of its thermometers were ended and discontinued. It took three months to sink it to the full depth of twenty-four feet, with a diameter of three inches at the bottom and six inches at the top; it was full of water always to a certain height while it was in progress, and was packed, when the thermometers were placed in it at their proper depths, with sand. A damp or wet state of the rock (and of the introduced sand) it may be gathered from these preserved accounts of its construction must have prevailed in the whole or a great part of the stratum of rock through which the bore-hole passed.

* Had the measurement of the specific heat of each porous plate been repeated with the rock *in its perfectly saturated state*, it is evident that the necessity of this correction would have been avoided. It is superfluous, apparently, for the sandstones *and less porous* rocks, for which one average error-range (for the wet and dry states together), only, is given in the table.

of common occurrence, and of very simple compositions. The high value found for white chalk, after deducting the above correction, perhaps arises from a considerable amount of hygroscopic moisture contained in the stone in its ordinary state; but, if on account of its extreme porosity

Rock Specimen tested	Thermal Conductivity: Observed, 1878. 0·00	Water absorbed, per cent.: In experiment	Water absorbed, per cent.: Maximum quantity	Average of previous observations, 0·00
Ordinary plate glass *; two plates...	201 / 195	[198	average]	204; plate glass, 1876
The same glass toughened; two plates	191 / 179	[185	average]	
Calton Hill trap, red, close grained ...	280	1·4	2·3	(520? 1874)
" " red, open grained ...	295	1·0	1·0	—
" " grey, weathered	360	0·4	1·0	-
Sicilian white marble.	508	—	—	542
Kenton sandstone	606	3·8	6·1	591 (wet; 5·7 p. c.)
Heworth "	641	2·9	4·5	
Prudham "	714	5·9	7·5	--
Galashiels (red) sandstone	741	6·6	8·4	—
Craigleith sandstone, Thermometer beds, top bed, T_1	854	2·7	6·5	—
Craigleith sandstone, Thermometer beds, top bed, T_2	681 / 661	2·3 / 0·5	5·9 / —	-
Craigleith sandstone, Thermometer beds, bottom bed, B_1 .	838	2·8	6·1	—
Craigleith sandstone, Thermometer beds, bottom bed, B_2 .	795	2·4	6·1	—
Craigleith sandstone, "Liver rock"	843	2·7	5·9	
Craigleith sandstone, "Bed rock"	749	3·0	5·8	—
Opaque white quartz (Morthoe, N. Devon)	862	—	--	738 (1876)

the whole (instead of half) of the correction noted in the Table is subtracted from the specific heat there given, the result, 0·190, is less instead of greater than the known value; and no real discordance of the observation from the known property of this porous stone can, therefore, be properly suspected, with a suitable allowance. The proportion of foreign mineral (which is compact quartz) contained in the specimen of galena may be calculated approximately from the specific gravity (4·90) of the specimen, which is less than the usual specific gravity (7·59) of galena; and the resulting specific heat of the galena alone, which appears to occupy in reality scarcely a half (47 per cent.) of the volume of the thick plate used in the experiments, agrees very fairly with this material substitution, with the specific heat by weight of pure galena given by Regnault.

* The plates of toughened and untoughened glass were obtained from makers in Berlin. Their average conductivities are respectively ·00185 and ·00198, showing a loss of $\frac{1}{15}$, or of $6\frac{1}{2}$ per cent. in the conductivity by toughening. The property of hard-drawn metal wires is probably analogous to this, which are known to be less perfect conductors of electricity than soft annealed ones. There is a sensible and nearly proportional difference, also, in the specific heats by weight; but none, apparently, in the specific gravities of the two plates. (See the accompanying list of this Report.)

The specific gravity as well as the specific heat of the specimen of English alabaster proves it (as moistening it with an acid also shows) not to be "oriental alabaster," or calcic carbonate, but calcic sulphate, or a semi-crystalline and compact form of a hydrate of that substance which appears

Substance	Authority	Specific Heat by weight —	Specific Heat by weight Observed 1878	Description of rock, and number of specimens tested (1878)
Coke (of anthracite)	Regnault	0·201	0·193	Gas-coke (1 specimen).
Coal	Crawford	0·278	0·287	Cannel-coal (3 specimens).
			0·374	Newcastle house coal (1 specimen).
Burnt Clay	Gladolin	0·185	0·188	Brick and firebrick (4 specimens).
White marble...	Regnault	0·216	0·210	White Sicilian and Italian marbles (2 specimens).
Grey marble ...	"	0·210	0·221	Other marbles (7 specimens).
White chalk ...	"	0·215	0·215 0·280	about ; Godstone chalk, Pure white chalk; 2 specimens
Silica (quartz)	"	0·191	0.187	Opaque white quartz (3 specimens). white sand 0·200
			0·195	Quartzite (2 specimens)
Sodic chloride...	"	0·214	0·192	Rocksalt (1 specimen).
Iron pyrites ...	"	0·130	0·126	Iron pyrites (1 specimen).
Galena............	"	0·051	0·084	Galena (with 28½ p. c. of quartz); 1 specimen.
			0·046	Galena (with 28½ p. c. of quartz; corrected for quartz).
			0·284	English alabaster (1 specimen).
Calcic Sulphate, anhydrous ...	"	0·197	0·260	Plaster of Paris (1 specimen, deducting half the poss. cor.)
Calcic Fluoride	—	—	0·200	Fluor-spar (1 specimen).

to agree in the property of its specific heat sensibly with plaster of Paris, although not with anhydrous calcic sulphate, to which Regnault assigns a

Substance tested, directly and indirectly, for Thermal Conductivity; and for Thermal Capacity by volume, and by weight	Specific Heat by volume c	Absolute Conductivity k	Value of the ratio $\frac{k}{c}$
Dry white sand (specific gravity, and specific heat tested directly, 1878; and thermal conductivity, directly, 1877) ...	0·292	0·00093	0·00318
White sand thoroughly wet (specific gravity, and specific heat tested directly 1878; and thermal conductivity, directly, 1877)	0·567 (?)	0·00726	0·01279 (?)
Sand of experimental garden (reduction of Professor Forbes's Thermometer Records, by Sir W. Thomson)	0·300	0·00262	0·00872

much lower specific heat by weight. These properties of minerals, like their specific gravities, certainly form very valuable and easily deter-

mined characters capable of affording most useful assistance as permanent and special qualities for distinguishing them from one another.

Another example of comparison between the direct and indirect methods of experiment has presented itself in the Committee's observations of Thermal Conductivities, where, however, they have not yet investigated the original substance which was the subject of the earlier experiments, but only an approximately similar one in two different conditions which permit a fair comparison of the measurements to be made, which have been obtained by direct, and also by a totally different method of procedure. The quantity of water (23 per cent.) found to be taken up by dry sand when thoroughly wet, as stated in the table, should raise its specific heat by weight from 0·200, there given, to 0·348; but the specific heat observed in the second case was only 0·284, corresponding to an absorption of only 12 per cent. of water. The specific heats by weight and by volume given in the table for thoroughly wet sand are, therefore, too low, and the value of the ratio $\frac{k}{c}$ deduced from them must be sensibly higher than its real value for saturated sand. For perfectly dry sand it is 0·0032, for thoroughly wet sand it must accordingly be about 0·0100, and for the sand in the experimental garden in Edinburgh, Sir W. Thomson obtained the value 0·0087, of the ratio $\frac{k}{c}$, by a reduction of the records of Professor Forbes' underground thermometers. Could a specimen of the sand itself, which the Committee hopes to procure, be obtained in which the thermometers were sunk, the value of the ratio found by Sir W. Thomson would no doubt be very closely corroborated; and, at the same time, the real values of the absolute conductivity and specific heat of a loose and porous earth like that in which these thermometers were placed, which the Committee has not yet determined, would be added to the present list.

The Committee has the satisfaction to notice with peculiar commendation the series of excellent and accurate experiments on the thermal conductivities and capacities of certain specimens of rocks of Japan, which the professors of the Tokio College there, Messrs. J. Perry and W. Ayrton, have conducted with the greatest skill and originality of method and of practical execution. Of the very excellent memoir of these experimenters, and of the contributions from other sources to the practical investigation of the subject of rock-conductivity which have been made recently and in bygone years, the Committee hope to point out the bearings in a collective review, if the production of such a historical report, during the coming year, presents itself as a sufficiently desirable object for their reappointment. Thin microscopic sections of about twenty of the rock-specimens upon which they have experimented have been prepared by Mr. G. F. Cuttell, of London, which convey much information to the eye regarding the causes of the various degrees of conductivity that are met with in particular rocks. The compact, almost purely siliceous nature of the quartzites is thus visibly presented, and the reason of their ranking with quartz much higher in conductivity than the more heterogeneous sandstones is very obvious. A similar minute inspection of the structure of Craigleith sandstone will no doubt furnish evidence of similar purity of its material in comparison with other sandstones, in explanation of the very distinctive quality of remarkably high thermal conductivity which it appears to possess among them.

TABLE OF SPECIFIC GRAVITIES AND POROSITIES, AND OF THE THERMAL CAPACITIES, CONDUCTIVITIES, AND RESISTANCES OF VARIOUS SPECIMENS OF ROCKS.

Class of Rock	Specimen of Rock tested	Specific Gravity:		Specific Heat: Dry (Wet)		Range of possible error; p.c.	Absolute Dry (Wet)		No. of observations	Value of the Ratio $\frac{k}{c}$
		Dry (Wet)	Gain [or water absorbed] p.c.	By Weight C	By Volume c		Conductivity k	Resistance		
Quartz and Quartzites	Opaque white quartz (Killarney)	2·54	—	0·18	0·45	—	·0084	119	5	·0187
	„ „ (Morthoe, N. Devon)	2·55	—	0·18	0·46	—	·0080	125	2	·0173
	Crystalline do. (north slope of Schiehallion)	2·52	—	0·19	0·48	—	·0092	109	1	·0191
	Pink quartzite (summit of Schiehallion)	2·56	—	0·19	0·49	—	·0091	110	1	·0184
	Yellow „ (north slope of Schiehallion)	2·55	—	0·19	0·49	—	·0086	117	1	·0175
	Ganister	2·59	—	0·19	0·49	—	—	—	—	—
	Quartz-Ironstone, in Gossan (Cornwall)	2·70 (2·75)	1·8	0·18 (0·20)	0·49 (0·54)	4·8	—	—	—	—
Granites	Aberdeen grey granite	2·63	—	0·19	0·51	—	·0053	188	3	·0104
	Peterhead red „	2·61	—	0·23	0·48	—	·0069?	145?	1	·0144?
	Loch Rannoch (fine) granite	2·66	—	0·19	0·52	—	·0052	193	2	·0100
	„ (coarse) „	2·60	—	0·20	0·51	—	·0050	199	1	·0098
	Swedish red granite	2·62	—	0·19	0·50	—	—	—	—	—
	Cornish Elvan	2·47 (2·54)	2·8	0·21 (0·24)	0·53 (0·60)	6·0	·0029	340	1	·0055
Whins and Trap-rocks	Whinstone (Whin Sill): two plates: av.	2·90	—	0·21	0·59	—	·0034	295	2	·0057
	„ (Kinnoul Hill, Perth)	2·74	—	0·21	0·57	—	—	—	—	—
	Blue Trap (south side of Loch Rannoch)	2·40	—	0·21	0·49	—	·0048	208	1	·0098
	Grey Trap (Pokham quarry, Exeter)	2·41 (2·47)	2·2	0·24 (0·25)	0·57 (0·63)	4·4	·0037	272	1	·0065
	Red „ (Pokham quarry, Exeter)	2·64	—	0·21	0·56	—	—	—	—	—
	„ „ fine-grained (Calton Hill)	2·44 (2·49)	2·3	0·21 (0·23)	0·52 (0·58)	5·1	·0028	357	1	·0054

Class of Rock	Specimen of Rock tested	Specific Gravity: Dry (Wet)	Specific Gravity: Gain [or water absorbed] p.c.	Specific Heat: Dry (Wet) By Weight C	Specific Heat: Dry (Wet) By Volume c	Range of possible error, p.c.	Absolute Dry (Wet) Conductivity k	Absolute Dry (Wet) Resistance	No. of observations	Value of the Ratio $\frac{k}{c}$
	Red Trap, coarse-grained (Calton Hill)	2·50 (2·53)	1·0	0·21 (0·22)	0·53 (0·56)	2·4	·0029	339	1	·0056
	Weathered Trap, coarse-grained (Calton Hill)	2·60 (2·63)	1·0	0·20 (0·21)	0·51 (0·54)	2·5	·0036	278	1	·0070
Mica-Schist and Flag-stones	Mica-Schist, loose-textured (Ilfracombe)	2·41	—	—	—	—	—	—	—	—
	„ indurated (Loch Rannoch)	2·77	—	0·20	0·53	—	·0046	216	1	·0087
	Indurated Flagstone (Loch Rannoch)	2·88	—	0·19	0·55	—	—	—	—	—
	„ „ light-coloured (Loch Rannoch)	2·74	—	0·19	0·53	—	—	—	—	—
	Flagstone* (Loch Rannoch), par. to cl. fine-grained (1)	2·37 (2·43)	2·3	0·21 (0·23)	0·50 (0·55)	5·2	·0045	221	1	·0091
	„ „ medium-grained (2)	2·70	—	0·19	0·52	—	·0044	225	1	·0085
	„ „ coarse-grained (3) ...	2·67	—	0·19	0·50	—	·0040	250	1	·0079
	„ „ coarse-grained, par. to cl. (A)	2·73	—	0·20	0·53	—	·0042	236	1	·0079
	„ „ fine-grained, par. to cl. (B)	2·66	—	0·19	0·51	—	·0048	207	1	.0095
	„ „ medium-grained, perp. to cl. (*a*)......	2·68	—	0·19	0·50	—	·0058	173	1	·0116
	„ „ medium-grained, perp. to cl. (*α*)......	2·70	—	0·19	0·51	—	·0059	170	1	·0114
	„ „ medium-grained, at angle of 40° to cl. (*b*)	2·71	—	0·19	0·52	—	·0053	188	1	·0103
	„ „ medium-grained, at angle of 60° to cl. (*β*)	2·68	—	0·19	0.51	—	·0068	147	2	·0133
Slate, Clay-slate, and Shales	Welsh slate, par. to cleavage	2·80	—	0·21	0·60	—	·0038	265	2	·0057
	Festiniog slate, par. to cl. (A and B, *ar*)	2·79	—	0·20	0·57	—	·0032	312	2	·0057
	„ perp. to cleavage	2·80	—	0·21	0·59	—	·0060	167	2	·0102

	Clay slate (Cristow, Exeter), par. to cl. (A and B, *av*)...	2·54 (2·56)	1·4	0·20 (0·21)	0·51 (0·54)	3·4	·0027	377	2	·0052
	” ” perp. to cl. ...	2·51 (2·56)	2·2	0·21 (0·23)	0·53 (0·59)	5·0	·0028	351	1	·0054
	Grey shale (Newcastle)...............................	2·65	—	0·23	0·60	—	·0027	374	1	·0044
	Black ” (Newcastle)...............................	2·18 (2·20)	0·8	0·29 (0·30)	0·63 (0·65)	1·3	·0015	676	2	·0023
	Altered shale (Wratcheugh Craig, Alnwick) par. to cl. (weathered)	2·27 (2·30)	2·0	0·22 (0·23)	0·50 (0·54)	4·4	·0031	318	1	·0063
	Altered shale (Wratcheugh Craig, Alnwick) perp. to cl. (solid)	2·57	—	0·21	0·55	—	·0041	244	1	·0074
Sandstones	Craigleith Sandstone: Top of Thermom. bed (T_1)	2·24 (2·39)	6·5	0·17 (0·22)	0·37 (0·52)	16·8	·0085	117	1	·0228
	Craigleith Sandstone: ” ” (T_2).......................	2·30 (2·43)	5·9	0·18 (0·22)	0·42 (0·54)	14·3	·0067	149	2	·0160
	Craigleith Sandstone: Bottom of ” (B_1)...........	2·19 (2·32)	6·1	0·19 (0·25)	0 41 (0·57)	14·0	·0084	119	1	·0202
	Craigleith Sandstone: ” ” (B_2).......................	2·22 (2·35)	6·1	0·19 (0·23)	0·42 (0·54)	14·5	·0079	126	1	·0188
	Craigleith Sandstone: “Liver Rock”	2·14 (2·27)	5·9	0·19 (0·24)	0·41 (0·54)	13·4	·0084	119	1	·0204
	Craigleith Sandstone: “Bed Rock”	2·18 (2·30)	5·8	0·18 (0·23)	0·40 (0·53)	13·8	·0075	133	1	·0186
	Heworth (Newcastle) sandstone	2·28 (2·38)	4·5	0·21 (0·25)	0·48 (0 59)	9·7	·0064	156	1	·0132
	Prudham (Newcastle) ”	2·15 (2·31)	7·5	0 18 (0 24)	0 39 (0 55)	17·5	·0071	140	1	·0182
	Kenton (Newcastle) ”	2·21 (2·35)	6·1	0 21 (0·25)	0·46 (0·59)	13·1	·0055 (·0059)	182 (168)	3 (1)	·0119 (·0100)
	Galashiels (red) sandstone	2·14 (2·32)	8·4	0·21 (0·27)	0·46 (0·64)	16·8	·0074	135	1	·0161
	Hard grit (Linton, N. Devon)	2·18 (2·33)	6·9	0·21 (0 26)	0·46 (0·60)	14·5	·0056 (·0061)	177 (165)	1 1	·0124 (·0101)
	Pennant sandstone (Bristol)	2·59	0·4	0·20	0·52	—	·0058	173	2	·0110
	Sandstone from Valley of Rocks, Linton	2·68	—	0·19	0·52	—	—	—	—	—
	Sandstone (greensand); (Godstone)	1·50 (1·83)	22·3	0·29 (0·42)	0·42 (0·76)	39·0 (22·0)	—	—	—	—

* The descriptions “parallel to the cleavage” (par. to cl.), perpendicular, or at an angle of 40°, &c., to the cleavage, denote the directions *of the faces* of the rock-plates tested, with respect to the natural planes of cleavage of the rock-specimens from which they were cut.

Class of Rock	Specimen of Rock tested	Specific Gravity: Dry (Wet)	Specific Gravity: Gain [or water absorbed] p.c.	Specific Heat: Dry (Wet) By Weight C	Specific Heat: Dry (Wet) By Volume c	Range of possible error; p.c.	Absolute Dry (Wet) Conductivity k	Absolute Dry (Wet) Resistance	No. of observations	Value of the Ratio $\frac{k}{c}$
Sandstones	Firestone (greensand); (Godstone)	1·56 (1·87)	20·4	0·28 (0·40)	0·43 (0·74)	36·0 (21·0)	·0021	474	2	·0049
Marbles	White Italian vein marble	2·74	—	0·21	0·58	—	·0051	195	2	·0088
	White Sicilian marble	2·72	—	0·21	0·57	—	·0054	186	5	·0095
	Red marble (Devonshire)	2·71	—	0·21	0·57	—	·0050	202	3	·0087
	„ (Cork)	2·71	—	0·21	0·57	—	—	—	—	—
	Irish green marble	2·65	—	0·22	0·60	—	·0051	197	1	·0085
	Irish fossil marble	2·70	—	0·21	0·56	—	·0052	193	3	0·0093
	Kilkenny fossil marble	2·73	—	0·20	0·55	—	—	—	—	—
	Frosterley „	2·68	—	0·25	0·66	—	—	—	—	—
	Dent (Cumberland) fossil marble	2·70	(0·6)	0·25	0·67	—	—	—	—	—
Compact Limestones and Calcitic Veinstuff	Mountain limestone (Loch Tummel) A and B „ „ (two plates, av.)	2·65	—	0·21	0·55	—	·0060 ?	167 ?	2	0 0109 ?
	Plymouth limestone, No. 1	2·54	(0·6)	0·19	0·49	—	—	—	—	—
	„ „ Nos. 2 and 3	2·63	—	0·21	0·55	—	—	—	—	—
	„ „ Nos. 4, 5, 6	2·60	—	0·21	0·54	—	—	—	—	—
	„ „ No. 7	2·57	—	0 21	0·53	—	—	—	—	—
	Calc. Veinstuff in M. limestone (Killarney)	2·70	—	0·21	0·58	—	·0060 ?	168 ?	1	0·0103 ?
	„ in Red Sandstone (Clifton)	2·68	(0·5)	0·21	0·57	—	·0047	214	1	0·0082
Building and Magnesian Limestones, and Chalk	Build. limestone (Mansfield, Notts)	2·25 (2·44)	8·1	0·21 (0·27)	0·47 (0·66)	16·5	·0060 ?	165 ?	1	0·0128 ?
	„ (Caen, Normandy)	1·99 (2·23)	11·8	0·24 (0·32)	0·48 (0·72)	24·0 (16·5)	·0043	231	2	·0089
	„ (Gt. Pyram. Casing-stone)	2·01 (2·24)	11·2	0·25 (0·32)	0·50 (0·72)	26·0 (15·5)	·0040	250	2	·0080
	Magn. limestone, compact (South Shields)	2·44 (2·50)	2·5	0·20 (0·22)	0·50 (0·56)	5·7	·0051	196	1	·0102
	„ „ porous, much magnesia (Castle Eden, Durham)	1·83 (2·16)	18·1	0·25 (0·37)	0·46 (0·80)	36 0 (21·0)	·0053	188	1	·0116

Sand, Clay, and Brick	Magnesite (Pignerol, Genoa)	1·83 (2·16)	18·0	0·22 (0·35)	0·41 (0·75)	40·0 (22·0)	—	—	—	—
	Chalk (Godstone)	1·65 (1·99)	20·1	0·27 (0·39)	0·44 (0·78)	39·0 (22·0)	·0020	500	1	·0046
	Pure white chalk	1·52 (2·07)	35·7	0·37 (0·37)	0·56 (0·76)	48·5 (27·5)	·0033	302	2	·0059
	Fine white sand	1·45 (2·00)	37·1 [22·7]	0·20 (0·28)	0·29 (0·57)	0·0	·0009 (·0073)	1075 (138)	1 1	0·0032 (·0128)
	Tough clay (sun-dried)	2·02 (1·83)	19·1 [26·4]	0·23 (0·46)	0·46 (0·85)	0·0	·0022 (·0031)	448 (322)	1 1	·0048 (·0035)
	Fire-brick (Newcastle); two plates; *av.*	1·81 (2·06)	14·3	0·185 (0·29)	0·33 (0·59)	39·0 22·0	·0017 (·0035)	575 (286)	1 1	·0053 (·0059)
	Old building brick (Newcastle)	1·71 (2·02)	18·1	0·20 (0·33)	0·34 (0·66)	0·0	—	—	—	—
	Red building brick	1·75 (2·06)	17·5	0·19 (0·31)	0·34 (0·65)	0·0	·0015 (·0025)	680 (405)	1 1	·0044 (·0038)
Coal and Coke	House coal (Newcastle)	1·26 (1·27)	0·9	0·37 (0·38)	0·17 (0·48)	1·2	·0006	1754	1	0·0012
	Cannel coal (Blaydon) (A)	1·39	(0·4)	0·29	0·41	(0·6)	·0011	885	2	·0027
	„ (Blaydon) (B)	1·39 (1·43)	3·1	0·27 (0·29)	0·38 (0·42)	5·4	—	—	—	—
	„ (Blaydon) (C)	1·36 (1·37)	0·9	0·30	0·40 (0·41)	1·5	—	—	—	—
	Gas coke	1·76 (1·81)	2·9	0·19 (0·21)	0·34 (0·39)	7·0	—	—	—	—
Serpentine, Alabaster, Rock Salt, &c.	Red serpentine (Cornwall)	2·57	—	0·27	0·70	—	·0044	227	2	·0065
	Green „ (Cornwall)	2·39 (2·44)	2·2	0·28 (0·29)	0·66 (0·71)	3·9	—	—	—	—
	English alabaster	2·29	—	0·28	0·65	—	·0042	236	2	·0063
	Plaster of Paris (a light plate: finest quality)	1·03 (1·56)	50·9	0·38 (0·59)	0·40 (0·92)	66·0 (28·5)	·0012 (·0016)	833 (625)	1 1	·0030 (·0017)
	Heavy spar	4·12	—	—	—	—	—	—	—	—
	Rocksalt	2·07	—	0·19	0·40	—	·0114	88	2	·0288
	Fluorspar	3·09	—	0·20	0·62	—	·0096	104	2	·0160
	Iron pyrites	4·66	—	0·125	0·585	—	—	—	—	—
	Galena (interspersed with 28 p.c. of quartz)	4·90	(0·5)	0·08	0·40	(2·6)	·0070	142	1	·0171
	Plate glass (two plates); *av.*	2·542	—	0·197	0·500	—	·00198	505	3	·00396
	The same glass, toughened (do.)	2·540	—	0·185	0·470	—	·00185	540	2	·00394

Report of the Committee, consisting of the Rev. H. F. BARNES-LAWRENCE, C. SPENCE BATE, *Esq.*, H. E. DRESSER, *Esq.* (*Sec.*), Dr. A. GUNTHER, J. E. HARTING, *Esq.*, Dr. GWYN JEFFREYS, Professor NEWTON, *and the* Rev. Canon TRISTRAM, *appointed for the purpose of inquiring into the possibility of establishing a "Close Time" for Indigenous Animals.*

IT is with regret that your Committee has to report that, for the first time since its original appointment in August 1868, the work it has not unsuccessfully had in hand has been brought in question, and this in a way which requires serious attention on the part of all who wish to preserve our indigenous animals from the extermination that, until the last few years, was threatening so many of them.

In July 1877, it having been reported to Her Majesty's Secretary of State for the Home Department that "the Herring Fishery on the coast of Scotland is in an unsatisfactory state, and that it is desirable that inquiries should be made to ascertain whether any legislative regulations would tend to promote the welfare of the fishermen engaged in the said fishery, and to increase the supply of herrings for the benefit of the public," that gentleman appointed Mr. Buckland, Mr. Spencer Walpole, and Mr. Archibald Young to be Commissioners to make such inquiries and to report to him the result thereof.

In accordance therewith the Commissioners above named reported to the Home Secretary, under date of March 1, 1878, and their 'Report,' with 'Appendices,' was subsequently presented to both Houses of Parliament by command of Her Majesty.

This 'Report,' containing certain conclusions arrived at by the Commissioners, naturally attracted the notice of your Committee; and after due consideration it was resolved that a letter should be addressed on behalf of your Committee to the Home Secretary in regard to some of those conclusions.

The following is a copy of the letter thereupon sent:—

"*To the Right Honourable R. A. Cross, H.M. Principal Secretary of State for the Home Department.*

"6 Tenterden Street, Hanover Square, W.,
"London, July 6, 1878.

"SIR,—The Committee of the British Association for the Advancement of Science, appointed for the purpose of inquiring into the possibility of establishing a close time for indigenous animals, having had under their consideration the 'Report on the Herring Fisheries of Scotland,' dated March 1, 1878, and the conclusions at which the Commissioners have arrived (pp. xxxv., xxxvi. of that Report), beg leave respectfully to submit to your consideration the following observations, viz.:—

"I. That conclusions Nos. 2 and 3 of the Commissioners—viz., that 'legislation in past periods has had no appreciable effect,' and that 'nothing that man has yet done, and nothing that man is likely to do,

has diminished, or is likely to diminish, the general stock of herrings in the sea'—if correct, are absolutely contradicted by conclusion No. 13, which recommends that 'The Sea-Birds Preservation Act, protecting gannets and other predaceous birds which cause a vast annual destruction of herrings, should be repealed in so far as it applies to Scotland.'

"II. That conclusion No. 1, stating that 'the Herring Fishery on the coast of Scotland, as a whole, has increased and is increasing,' clearly shows that there can be no necessity for the step recommended in conclusion No. 13 as above cited.

"III. That conclusion No. 13 seems to have been arrived at from exaggerated or incorrect information, as will appear from the following considerations:—The number of gannets on Ailsa is estimated (Report, p. xi.) at 10,000, and a yearly consumption of 21,600,000 herrings is assigned to them; while the Commissioners assume that there are '50 gannets in the rest of Scotland for every one on Ailsa,' and on that assumption declare that the total destruction of herrings by Scottish gannets is more than 1,110,000,000 per annum. This is evidently a miscalculation; for, on the premisses, this last number should be 1,101,000,000, a difference of more than 8,000,000.

"But, more than this, supposing the figures at the outset are right, it appears to the Close Time Committee that the succeeding assumption of the Commissioners must be altogether wrong; at any rate there is no evidence adduced in its support, and some that is contradictory of it.

"The number of breeding-places of the gannet in the Scottish seas has long been known to be five only, as, indeed, is admitted by one of the Commissioners (Appendix No. 2, p. 171); and the evidence of Captain M'Donald, which is quoted in a note to the same passage, while estimating the Ailsa gannets at 12,000 in 1869 (not 1859, as printed), puts the whole number of Scottish gannets at 324,000 instead of 510,000, which there would be at the rate of 50 in the rest of Scotland for one on Ailsa, according to the Commissioners' assumption.

"Moreover, 50,000 of these 324,000 birds, or nearly one-sixth, are admitted by this same Commissioner to be 'of great value to the inhabitants' of St. Kilda; and, indeed, they are of far greater value to them than any number of herrings, since it is perfectly well known that the people of St. Kilda could hardly live without their birds; therefore this 50,000 must be omitted from any estimate of detriment. Deducting, then, 50,000 from Captain M'Donald's 324,000, we have 274,000, and these, at the Commissioners' estimate, would consume 600,060,000 herrings instead of the 1,110,000,000 alleged by the Report, and, therefore, nearly 200,000,000 fewer than the Commissioners' estimate of the annual take of the Scottish fisheries (800,000,000)—25 per cent. less, instead of 37 per cent. more.

"Hitherto the supposition of the Report, that the gannets frequent the Scottish seas all the year round, has been followed; but the Close Time Committee begs leave to observe that, as a matter of fact, these birds are not there in force for more than half the year.

"This, then, will require another abatement to be made. Not to exaggerate the case, the Committee assumes them to frequent those waters seven months, or seven-twelfths of a year. This will make their annual capture of herrings 350,350,000, instead of the more than 1,110,000,000

of the Commissioners, being nearly 700,000,000, or much less than one-third, fewer.

"IV. That in all the evidence received and published by the Commissioners only two witnesses allege that any harm has resulted to the fisheries from the Sea-Birds Protection Act. Of these, the first, Robert M'Connell, presented a petition from the fishermen of Girvan, in which it is stated (p. 145) that 'no legislation is called for or required;' while another witness from the same place, John Melville (a fishery officer), declares (at p. 146) that 'the fishery has very much increased this last year. Recent years have also shown a gradual increase. The increase is partly due to the increased machinery, and partly to the increase in the number of herrings.'

"The second witness unfavourable to the Act, John M'William (an Inspector of Poor), speaks (pp. 147–49) only from personal knowledge acquired between 1833 and 1853, when he ceased to be a fisherman, and not from any recent experience. He can therefore scarcely be held competent to give an opinion of his own as to whether the Sea-Birds Protection Act (passed in 1869) has injured the fisheries. Another witness recommends the repeal of this Act; but he, Hugh MacLachlan, expressly states (p. 143) that he 'thinks the cause of the decrease [in the number of herrings taken] is the catching immature fish;' and the remedy he proposes is the adoption of a strict close time.

"V. That, on the other hand, the utility of sea-birds in pointing out the situation of shoals of herrings and other fish is not only generally notorious, but is even admitted in the Report (pp. 57 and 175).

"VI. That if the Sea-Birds Act be repealed on the grounds alleged for Scotland, its repeal for England and Ireland must logically follow; and this Committee trusts that no steps may be taken to repeal the Act for Scotland.

"I am, Sir,
"Yours obediently,
"H. E. DRESSER,
"*Sec. to the Brit. Assoc. Close Time Committee.*"

To this letter the following reply has been received:—

Whitehall, July 12, 1878.

"SIR,—I am directed by the Secretary of State to acknowledge the receipt of your letter of the 6th inst., submitting observations on behalf of the Committee of the British Association for the Advancement of Science on the Report of the Commissioners appointed to inquire into the herring fisheries of Scotland, dated the 1st March last.

"I am, Sir,
"Your obedient servant.
(Signed) "GODFREY LUSHINGTON.

"H. E. Dresser, Esq.,
6 Tenterden Street, Hanover Square, W."

Your Committee conceives that the points at issue between it and the Scottish Herring Fishery Commissioners are thus fairly stated, and is confident that all unbiassed persons will admit that those Commissioners have over-stated their case. Your Committee would further remark that,

though the Sea-Birds Preservation Act contains a provision (in section 3) for varying the close time therein enacted on due application, no such application appears ever to have been made on the ground of detriment to the herring fisheries caused by sea-birds; while there can be no reasonable doubt that any application for shortening the close time on that ground, if duly made, would be granted—circumstances which would seem to show that the conclusions of the Commissioners were not generally shared by those interested in the fisheries. On the other hand, your Committee may refer to the fact, already mentioned in former Reports, that several applications have been made for prolonging the existence of the close time.

With regard to the Wild-Fowl Preservation Act your Committee has to report that the discontent caused by its establishing a close time, different from that which was originally proposed by your Committee, still exists in some quarters, but that the power of variation the Act contains has been put in force in many counties; and your Committee trusts when this power has been still further exercised, as it doubtless will be, and the Act practically brought into accordance with your Committee's first proposal, of which there are many indications, dissatisfaction will be reduced to a *minimum*, or will altogether cease.

A Bill for the Protection of Freshwater Fish has been introduced into Parliament during the present Session, and will doubtless receive the Royal assent. It has not, however, been of a kind that needed any action on the part of your Committee.

In view of any proceedings which may be taken in the Session of 1879 in regard to the recommendations of the Scottish Herring Fishery Commissioners already recited, as well as on general grounds, your Committee respectfully urges its reappointment.

Report of the Committee appointed for the purpose of arranging with Dr. DOHRN *for the occupation of a Table at the Zoological Station at Naples; the Committee consisting of* Mr. DEW-SMITH (*Secretary*), Professor HUXLEY, Dr. CARPENTER, Dr. GWYN JEFFREYS, Mr. SCLATER, Dr. M. FOSTER, Mr. F. M. BALFOUR, *and* Professor RAY LANKESTER.

YOUR Committee have the honour to report that the working of the Zoological Station is proceeding in the most satisfactory manner, and that its efficiency has greatly increased since the last report was made.

Since August 1, 1877, no less than twenty-one naturalists have been engaged in working at the Station, which is a larger number than in any former year.

The steam launch presented by the Berlin Academy of Sciences has been of great service in providing animals found at a distance from Naples, and of short-lived animals requiring rapid transit, to enable them to be used in a sufficiently fresh condition.

Of late, one of the main objects of the Station has been largely developed, viz., the supplying of animals for research, and for museum specimens at a small cost to persons applying for them.

The animals are procured and preserved by the staff at the Station, and are sent off and charged for at the bare cost of the animals, plus the cost of the preservation solutions.

Since August 1, 1877, packages of specimens have been sent to forty-nine different naturalists residing in various parts of the world. A list is appended to this report, giving the names of those to whom the specimens were sent, and also the nature of the specimens themselves.

The scientific work of the Station is progressing well, as the following list of monographs preparing for publication will show:—

On Ctenophoridæ	By Dr. Chun.
„ Balanoglossus	„ Dr. Spengel.
„ Sipunculoidæ	„ Dr. Spengel.
„ Capitellidæ (Annelida)	„ Dr. Eisig.
„ Caprellidæ	„ Dr. Mayer.
„ Pycnogonidæ	„ Dr Dohrn.
—	„ Dr. Emery.
„ Hyperidæ	„ Dr. Mayer.

Also several algological monographs by Dr. Falkenberg, Dr. Schaützt, and Professor Solms-Laubach are nearly ready, besides many papers on minor investigations

We hear that the monographs on Ctenophoridæ, by Dr. Chun, and on Balanoglossus, by Dr. Spengel, are already in the press.

We very much regret that no naturalists have availed themselves of the use of the table engaged by the Association, and we would suggest that members should endeavour to make it more widely known that naturalists desirous of working at some group of animals may, with the consent of the Committee, proceed to Naples, and there find every convenience for their work, including material and use of the steam launch for dredging purposes, supplied to them free of all cost.

Lastly, we very strongly urge the desirability of renewing the grant of £75, as although, as we have shown, the Station is in a most prosperous condition, still it can only remain so when liberally supported by public bodies interested in the advancement of science.

List of the Naturalists who have worked in the Station from August 1, 1877, *to August* 1, 1878.

Prof. Th. Eimer, Tübingen	Table	Würtemberg	18 August	1877	to	4 September 1877
Dr. Bonnet, Munich	„	Bavaria	20 „	„	„	1 „ „
Prof. Stendner, Halle	„	Prussia	25 „	„	„	15 October „
Prof. His, Leipzig.	„	Saxony	7 September	„	„	27 September „
Prof. Graf Salms-Laubach, Strasburg	„	Strasburg	26 „	„	„	24 October „
Dr. Taschenberg, Leipzig	„	Saxony	3 November	„	„	28 June 1878
Dr. P. Mayer, Lüdenscheidt	„	Prussia	1 January	1878	„	—
Dr. Zincone, Naples	„	Italy	1 „	„	„	
Dr. De la Valle, Naples	„	Italy	1 January	1878	„	

Dr. A. Lang, Berne ...	Table	Switzerland	14 January	1878	to	7 May	1878
Dr. Schmitz, Kassel ...	„	Prussia	22 „	„	„	30 June	„
Dr. R. Valiante, Naples	„	Italy	11 February	„	„	—	„
Dr. E. Everts, Hague	„	Holland	11 March	„	„	18 May	„
Dr. V. Koch, Darmstadt	„	Darmstadt	12 „	„	„	24 „	„
Prof. Graf Salms-Laubach, Strasburg......	„	Strasburg	14 „	„	„	25 April	„
Dr. C. Chun, Frankfort	„	Berlin Academy	14 „	„	„	28 „	„
Dr. v. Rohlfs, Leipzig	„	Saxony	20 „	„	„	18 May	„
Dr. L. Graff, Aschaffenburg....................	„	Bavaria	31 „	„	„	12 „	„
Professor Metchinkoff, Odessa.................	„	Russia	17 „	„	„	3 June	„
Prof. v. Rougemont, Neuchatel	„	Switzerland	8 May	„	„	2 July	„
Dr. Emery, Naples ...	„	Italy	28 June	„	„	—	

List of Naturalists and Places to which Animals have been sent from August 1, 1877, *to August* 1, 1878.

Aug. 1877.			
1	Dr. M. Lanzi	Rome	Salpæ.
3	Mr. Balfour	Paris	Ascidia.
3	Dr. Grobben	Vienna	Crustacea.
3	Prof. Studer	Berne	Salpæ, Coelenterata.
Sept.			
10	Prof. Eimer	Tübingen	Selachia.
22	Prof. Greeff	Marburg	Miscellaneous.
Oct.			
30	Prof. Götte	Strassburg	Embryos of Torpedo, and Scyllium.
30	Prof. Heller	Innsbruck	Crustacea.
Nov.			
5	Anat. Institute	Halle	Miscellaneous.
5	L. Blaschka	Dresden	Mollusca, Coelenterata.
28	Prof. Hoffmann	Leyden	Miscellaneous.
28	Kgl. Naturaliencab.	Stuttgart	do.
Dec			
19	Prof. Ausserer	Graz	do.
31	Museo Zoologico	Palermo	Fishes.
31	W. Percy Sladen	Halifax	Echinodermata.
31	Prof. Greeff	Marburg	Echinod., Coelent.
31	Zool. Museum	Berlin	Miscellaneous.
Jan. 1878.			
10	Kgl. C. Thierarznei-Schule	Munich	do.
12	Professor Kollmann	Munich	Heteropoda and Pteropoda.
28	Prof. F. E. Schulze	Graz	Spongidæ.
28	Zool. Station	Trieste	Hydromedusæ.
Feb.			
4	C. Armbruster	London	Cephalopoda.
4	Prof. Ehlers	Göttingen	Coelent., Echinod.
4	Dr. Emery	Palermo	Eyes of fishes.
4	A. Waters	Woodbrook	Bryozoa.
March			
9	Prof. Semper	Würzburg	Lamellibranchiata.
9	Prof. Todaro	Rome	Miscellaneous.
30	H. Karthaus	Marburg	do.
30	Dr. Ludwig	Göttingen	Echinodermata.

1878 April			
8	C. Stacy Watson	London	Fishes.
16	Prof. Claus	Vienna	Coelenterata.
30	Prof. Eimer	Tübingen	Fishes, Echinod., Coelent.
30	K. Felsche	Leipzig	Brachyura.
30	Dr. v. Thering	Erlangen	Mollusca.
30	Prof. Leuckart	Leipzig	Miscellaneous.
May			
7	Dr. Lang	Berne	do.
11	Dr. Everts	Hague	do.
14	Prof. Graff	Aschaffenb.	do.
15	Prof. Hoffmann	Leyden	Eyes of Cephalop. and Pterop.
18	Dr. de Man	Leyden	Mollusca.
19	Zool. Cabinet	St. Petersburg	Hydra polyps.
25	Prof. v. Koch	Darmstadt	Mollusca, Coelent.
25	Prof. Steindachner	Vienna	Fishes, Coelent.
June			
29	Prof. de Rougemont	Neuchatel	Fishes.
29	Zoolog. Institute	Halle	Miscellaneous.
July			
27	Zoolog. Museum	Berlin	do.
31	K. Heider	Graz	Coelent.
31	Leeds Museum	Leeds	Mollusca, Fishes, Coelent., Vermes.
31	Dr. Preper	Olfen	Miscellaneous.

Report of the Anthropometric Committee, consisting of Dr. FARR, Lord ABERDARE, Dr. W. BAIN, Dr. BEDDOE, Mr. BRABROOK, Sir GEORGE CAMPBELL, Captain DILLON, The EARL OF DUCIE, Professor FLOWER, Mr. DISTANT, Mr. F. P. FELLOWS, Mr. F. GALTON, Mr. PARK HARRISON, Mr. J. HEYWOOD, Mr. P. HALLETT, Major-Gen. LANE FOX (*Sec.*), Inspector-General LAWSON, Mr. GEORGE SHAW LEFEVRE, Professor LEONE LEVI, Dr. WALLER LEWIS, Dr. MOUAT, Sir RAWSON RAWSON, Mr. ALEXANDER REDGRAVE, and Professor ROLLESTON.

A CONSIDERABLE delay has been unavoidably incurred in preparing and circulating the schedules and accompanying instructions for collecting the desired observations, with a view of testing by practical experience the extent to which the Committee might look for useful results, and the sufficiency of the instructions to ensure both accuracy and uniformity. The work, therefore, has hitherto been rather tentative and experimental.

The forms and instruments used by the Committee are: (1). Explicit instructions to observers on the mode of filling-in the blank schedules, and on the use of the instruments. (2). A schedule for the measurements and other observations. This contains, when full, twenty names. (3). A printed circular, by Dr. Farr, explaining the objects of the Committee. (4). Book of tinted papers, named and numbered, to assist observers in specifying the different colours of the hair. (5). A circular by Mr. Brabrook, in relation to photographs. (6). A diagram showing

the position in which the strength of arm should be tested; and (7) a card containing dots for testing eyesight.

The instruments are: (1). A weighing machine. (2). A simple apparatus for measuring height. (3). A spirometer; and (4) a spring balance for testing strength of arm. Of these instruments the Committee have purchased four complete sets.

A great number of the forms have been distributed to persons in various parts of the country.

The schedules already filled up and received by the Committee relate to the measurements of the boys at Westminster School, the 2nd Royal Surrey Militia, letter-sorters in the General Post Office, recruits, persons employed in a large manufactory in Bedford, criminals; and a few relate to persons engaged in different occupations. Some of these, however, have not been taken strictly according to the instructions drawn out by the Committee, and some of them are of less value than the rest.

Other measurements have been promised by Dr. Mouat; by the Rev. George Style, the head-master of a grammar-school in Yorkshire; by Dr. Farr; and by Capt. Brown, of the 18th Kent Rifle Volunteers. Capt. Brown states, in his letter to Dr. Farr, that he will have much pleasure in furnishing measurements of the men in his corps—about 100; and that he will see personally the other eight commanding officers, and ask them to assist the Committee. Should Capt. Brown be able to obtain the whole, they will amount to about 900 men.

Amongst those who have furnished the Committee with measurements may be mentioned the names of Major-General Lane Fox, Mr. Francis Galton, Inspector-General Lawson, Dr. Waller Lewis, Dr. Bain, Dr. Scott, the head-master of Westminster School, and Professor Rudler.

A few sets of tables have been prepared from the above returns, showing the age and height, age and weight, age and strength, and average height, weight, and strength, as well as the ratio between height and weight and the ratio between height and strength.

An extract from the tables relating to criminals has been drawn out by Mr. Francis Galton, as an illustration of one of the methods in which it is proposed to deal with facts collected by the Committee, to be circulated with their forms and instructions.

General Lane Fox has written a full report on the measurements, which he personally superintended, of the 2nd Royal Surrey Militia; and from which he has prepared several tables, which are shown at the end of his report. His tables, though differently constructed, agree in nearly every particular with those prepared under the direction of Dr. Farr.

It will be observed that several gentlemen have promised to furnish the Committee with measurements, and they hope soon to be in possession of such facts as will enable them to compare the results with the different classes of the population, and to determine the physical characters of persons born and living in different parts of the country.

In the meantime the Committee abstain from submitting incomplete results; they, however, think the following short abstract from some of the tables alluded to may be of sufficient interest to deserve consideration.

Age	Class	Number of persons at each age	Averages: Average height in inches	Averages: Average weight in pounds	Averages: Average strength of arm in pounds	Ratio between height and weight: Number of pounds in weight to an inch in height	Ratio between height and strength: Number of pounds in strength to an inch in height
13	Non-commissioned officers and men 2nd Royal Surrey Militia	—	—	—	—		-
	Boys at Westminster School	20	59 7	86·2	47·8	1·4	0·8
	General Post Office (letter-sorters, &c.)	36	55·9	74·7	—	1·3	–
14	Non-commissioned officers and men 2nd Royal Surrey Militia	—	—	—	-	—	-
	Boys at Westminster School	48	61·3	95·3	55·6	1·6	0·9
	General Post Office (letter-sorters, &c.)	503	60·3	93·3	—	1·5	—
15	Non-commissioned officers and men 2nd Royal Surrey Militia	—	-	-	-	—	—
	Boys at Westminster School	39	64·8	111·5	59·1	1·7	0·9
	General Post Office (letter-sorters, &c.)	670	61·7	100·5	—	1·6	—
16	Non-commissioned officers and men 2nd Royal Surrey Militia	4	64·5	122·5	61·3	1·9	1·0
	Boys at Westminster School	43	66·5	124·2	69·8	1·9	1·0
	General Post Office (letter-sorters, &c.)	275	63·9	111·5	—	1·7	-
17	Non-commissioned officers and men 2nd Royal Surrey Militia	13	64·0	119·4	61·7	1·9	1·0
	Boys at Westminster School	18	67·8	129·6	81·6	1·9	1·2
	General Post Office (letter-sorters, &c.)	124	65·4	120·5		2·0	-
18	Non-commissioned officers and men 2nd Royal Surrey Militia	35	64·7	126·2	67·1	1·9	1·0
	Boys at Westminster School	8	67·5	138·1	92·5	2·0	1·4
	General Post Office (letter-sorters, &c.)	98	65·4	123·3		1·9	- -

For the purpose of inquiring into and determining the typical forms of our race a sub-committee has been formed, consisting of Mr. Brabrook, Sir Rawson Rawson, Major-General Lane Fox, Mr. Francis Galton, Mr. Park Harrison, Professor Leone Levi, and Mr. Distant.

The Report of the Sub-Committee is annexed hereto.

In conclusion, it may be said that the Committee have now organised the system of observations, and have tested them sufficiently; they have distributed blank schedules, which they expect to have returned to them

filled up; they have also agreed on the more important points concerned in the forms of reduction of the raw materials.

They are now prepared with instruments sufficient to enter upon a large field of observation.

They have expended £83 11s. 2d. in their prefatory work of the £100 that was voted to them, and have handed the residue back to the Treasurer. They now beg that the residue be re-granted to them, together with an additional sum of £83 11s. 2d., which will put them in possession of £100 to carry on operations during the next year, which they trust will produce a valuable harvest of results.

WILLIAM FARR,
July, 1878. *Chairman of Anthropometric Committee.*

REPORT OF SUB-COMMITTEE.

The Sub-Committee appointed by the Anthropometric Committee to deal with that portion of the reference to them which relates to "the publication of photographs of the typical races of the empire," resolved in the first instance to limit the inquiry to the investigation, by means of photographs, of the national or local types of races prevailing in different parts of the United Kingdom.

The plan which the Sub-Committee thought it best to adopt was to select a number of districts in which it is believed a distinct type prevails, and in each such district to request the assistance of as many competent observers as can be found; each to be asked to obtain a limited number of photographs, six to ten, representing in his opinion the type chiefly prevalent among individuals belonging to families long settled and intermarrying in the district. From the materials thus obtained, the Sub-Committee hope to be able to select representative specimens.

In the carrying out of this plan, the assistance of professional and amateur photographers, of medical men, and of clergymen, has been sought. A circular has been addressed to about a hundred members of the Association, and a letter has been published, by authority of the Committee, in the 'Photographic News.' This inquiry is one, however, in which almost every member of the Association may be able to assist, and the Sub-Committee (presuming the Association will authorise the continuance of the work) appeal to the members generally for such assistance.

The Sub-Committee recommend—

1. That the selected individuals should be adults.
2. That the details of their pedigree, as far as possible, should be given.
3. That, in general, only those should be accepted whose two parents and four grandparents were born in or belonged to the district.
4. That the colour of hair and eyes should be stated, if practicable.
5. That the photographs should be accompanied by a written description of the particular features they portray as being characteristic of the district.

In pursuance of this plan, the Sub-Committee have received from Professor Rudler an excellent selection of 5 male and 5 female inhabitants of Aberystwith, which are laid upon the table, as specimens of the way in which the work should be done. Mr. Park Harrison, one of their body, has made a selection of types from Wales and Cornwall, and others from

Sussex and East Kent. Miss Whitmore-Jones, of Chastleton House, Oxfordshire, has kindly arranged for the photographing of some of the inhabitants of that parish whose pedigree can be traced in the parish registers up to their very commencement, nearly 300 years ago. (Six groups thus obtained are laid upon the table.) Mr. Hooper, a skilled photographer, has promised to furnish the Sub-Committee with specimens from several districts. They have had also most liberally placed at their disposal the important collections which have been made during many years past by their colleague, Dr. Beddoe. The Rev. Mr. Crompton, in Norfolk, Mr. Spence Bate, in Cornwall, Mr. C. Staniland Wake, at Hull, Mr. Sorby, at Sheffield, Dr. Muirhead, for Scotland, and numerous others, have also kindly undertaken to collect photographs for the Sub-Committee. Collectors for Ireland are much wanted.

Though the Sub-Committee are as yet only on the threshold of their task, and their operations have been hitherto tentative, they are hopeful of useful results. Their sense of the importance and interest of the work has grown with every step they have taken, and it is abundantly clear that, if not now completed, it will become more and more difficult in future years. The influence of railways has during the last fifty years greatly increased migration and intermixture, and that influence must increase instead of diminishing. It has indeed been suggested to the Sub-Committee by some of their correspondents that the requirement as to pedigree is already too onerous for urban and manufacturing districts, and that in such cases it will be necessary to be content with proof that a mere majority of the three generations, and not the whole, belong to the district.

The Sub-Committee respectfully recommend that they be reappointed, with the view of pressing forward the work to completion. They would be glad if a few practical photographers could be added to their number; and they again ask for the assistance of any competent persons who will undertake to select six or ten typical photographs in the district they know best, and for any other aid in carrying out the undertaking that the members can give.

In connexion with this branch of the subject, the Sub-Committee have watched with much interest the experiments of their colleague, Mr. Francis Galton, in preparing compound photographs from several individuals belonging to the same category. In dealing with the features of criminals, Mr. Galton has produced some remarkable results, and the Sub-Committee will not fail to inquire whether an application of his process would not be useful for their own purposes in generalising the peculiar features observed in different localities.

Though the Sub-Committee have of necessity postponed the collection of photographs of races of the empire outside the United Kingdom, Sir Rawson Rawson has been kind enough to obtain for them from the Colonial Office a set of the very fine series of photographs which that department obtained some years ago under the advice of Professor Huxley; and the authorities of the India Office have also kindly placed at the disposal of the Sub-Committee their valuable collection of photographs of Indian races.

For the Sub-Committee,
E. W. BRABROOK.

July, 1878.

Report of the Committee, consisting of Dr. A. W. WILLIAMSON, Professor Sir WILLIAM THOMSON, Mr. BRAMWELL, Mr. ST. JOHN VINCENT DAY, Dr. C. W. SIEMENS, Mr. C. W. MERRIFIELD, Dr. NEILSON HANCOCK, Mr. F. J. ABEL, Mr. J. R. NAPIER, Captain DOUGLAS GALTON, Mr. NEWMARCH, Mr. E. H. CARBUTT, *and* Mr. MACRORY, *appointed for the purpose of watching and reporting to the Council on Patent Legislation.*

THIS Committee begs leave to report that, with the exception of the introduction of a Bill on the Patent Law by a private member, which Bill was not proceeded with, there has not been any attempt at legislation on the subject. The Committee request that they may be reappointed.

Report of the Committee, consisting of Mr. W. H. BARLOW, Mr. H. BESSEMER, Mr. F. J. BRAMWELL, Captain DOUGLAS GALTON, Sir JOHN HAWKSHAW, Dr. C. W. SIEMENS, Professor ABEL, *and* Mr. E. H. CARBUTT (*Sec.*), *appointed for the purpose of considering the Use of Steel for Structural Purposes.*

OWING to the action of your Committee, the Board of Trade requested two of your members, viz., Sir John Hawkshaw, F.R.S., and Mr. W. H. Barlow, F.R.S., to co-operate with Colonel Yolland, "to consider whether it is practicable to assign a safe co-efficient for steel."

After a long and careful consideration they, on March 19, 1877, reported as follows:—

"We assume that with steel, as with iron, the engineer will take care that, as well as the required strength, he secures a proper amount of ductility.

"Having given the subject our best consideration, we recommend that the employment of steel in engineering structures should be authorised by the Board of Trade under the following conditions, namely:—

"1. That the steel employed should be cast steel or steel made by some process of fusion, subsequently rolled or hammered, and that it should be of a quality possessing considerable toughness and ductility, and that a certificate to the effect that the steel is of this description and quality should be forwarded to the Board of Trade by the engineer responsible for the structure.

"2. That the greatest load which can be brought upon the bridge or structure, added to the weight of the superstructure, should not produce a greater strain in any part than $6\frac{1}{2}$ tons per square inch.

"In conclusion we have to remark that in recommending a co-efficient of $6\frac{1}{2}$ tons per square inch for the employment of steel in railway structures generally, we are aware that cases may and probably will arise when it will be proposed to use steel of special make and still greater tenacity, and when a higher co-efficient might be permissible; but we think those

cases must be left for consideration when they arise, and that a higher co-efficient may be then allowed in those instances where the reasons given appear to the Board of Trade to justify it.

"We are, &c.,

(Signed) "JOHN HAWKSHAW,
"W. YOLLAND,
"W. H. BARLOW.

"The Secretary of the Board of Trade, &c."

This Report has since been acted upon by the Board of Trade in the printed paper issued by them in reference to railway structures.

It will be observed that a co-efficient of $6\frac{1}{2}$ tons per square inch is assigned to steel, that of iron being 5 tons per square inch.

This increase of the co-efficient will effect important economy in structures, especially in bridges of large spans, and will also tend generally to increase the employment of steel for railway and shipbuilding purposes.

The labours of your Committee having ended in such a satisfactory manner, there is no necessity to reappoint them.

Report on the Geographical Distribution of the Chiroptera. *By* G. E. DOBSON, *M.A., M.B.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

IN his work on the Geographical Distribution of Animals, published scarcely two years ago, Mr. Wallace writes:—"The genera of Chiroptera are in a state of great confusion, the names used by different authors being often not at all comparable, so that the few details given of the distribution of the bats are not trustworthy. We have therefore made little use of this order in the theoretical part of the work." And again: "The bats are a very difficult study, and it is quite uncertain how many distinct species there are; the genera are exceedingly numerous, but they are in a very unsettled state, and the synonymy is exceedingly confused. The details of their distribution cannot therefore be usefully entered upon here."

These remarks furnish a suitable preface to this paper. The recent publication of my work on the Chiroptera renders them, I hope, no longer applicable, and I purpose now to set forth in greater detail the results of my inquiries into the geographical distribution of these animals than the space at my disposal in the introduction to the work referred to has permitted.

Mr. Wallace points out the pre-eminent importance of the distribution of Mammals in determining the limits of zoological regions; but also remarks that, "there are two groups which have quite exceptional means of dispersal—the bats which fly, and the cetacea, seals, &c., which swim. The former are capable of traversing considerable spaces of sea, since two

North American species either regularly or occasionally visit the Bermudas, a distance of 600 miles from the mainland."

I do not think that the occurrence of two American species of bats in the Bermudas affords much proof of the general capability of the species of Chiroptera in traversing considerable spaces of sea, for it is exceedingly probable that the few individuals which have been noticed there have been carried thither by storms (to which cause is evidently due the great number of straggling species of birds which have been found there), or have been imported into the island while hybernating in the holds of vessels, or are the descendants of such accidentally imported individuals. However, even if it be granted that the Chiroptera possess great powers of dispersal, it is certain that quite nine-tenths of the species avail themselves of them in a very limited degree indeed, and it is significant that the distribution of the species is limited by barriers similar to those which govern it in the case of other species of mammals. This is well shown by the small number of species which are known to inhabit more than one of the recognised zoological regions, which amount to 22 only out of 400. The following list includes these species, and shows also their distribution.

1. *Pteropus hypomelanus* .... Australian and Oriental.
2. *Macroglossus minimus* .... Oriental and Australian.
3. *Rhinolophus ferrum-equinum* .... Ethiopian and Palæarctic.
4. *Vesperugo serotinus* .... All regions except the Australian.
5. *Vesperugo noctula* .... Ethiopian, Oriental, Palæarctic.
6. *Vesperugo maurus* .... Oriental and Palæarctic.
7. *Vesperugo abramus*........................ Oriental and Australian.
8. *Vesperugo Kuhlii* .... Oriental and Palæarctic.
9. *Nycticejus crepuscularis* .... Nearctic and Neotropical.
10. *Atalapha noveboracensis* .... Nearctic and Neotropical.
11. *Atalapha cinerea* .... Nearctic and Neotropical.
12. *Harpiocephalus harpia* .... Oriental and Australian.
13. *Vespertilio adversus* .... Oriental and Australian.
14. *Vespertilio capaccinii* .... Oriental and Palæarctic.
15. *Vespertilio daubentonii* .... Palæarctic and Oriental.
16. *Vespertilio muricola* .... Oriental and Australian.
17. *Vespertilio lucifugus* .... Nearctic and Neotropical.
18. *Kerivoula hardwickii*...................... Oriental and Australian.
19. *Miniopterus schreibersii* .... Oriental, Australian, Ethiopian, and Palæarctic.
20. *Taphozous nudiventris* .... Ethiopian, Oriental, and Palæarctic.
21. *Rhinopoma microphyllum*............... Ethiopian, Oriental, and Palæarctic.
22. *Nyctinomus brasiliensis* .... Neotropical and Nearctic.

Estimating the total number of known species of Chiroptera at 400, it follows that $5\frac{1}{2}$ per cent. only wander beyond their respective zoological regions, or, in other words, $94\frac{1}{2}$ per cent. are characteristic. It is also noticeable that more than two-thirds of these wandering species belong to the family Vespertilionidæ, which has by far the widest geographical distribution, and includes the least specialised forms.

The following table exhibits the numbers of families, genera, and species inhabiting each zoological region; and shows that in the regions situated principally within the tropics (as the Oriental and Neotropical regions) the number of species is more than three times that of those lying chiefly in the temperate zones (as the Nearctic and Palæarctic regions).

	Palæarctic			Ethiopian			Oriental			Australian			Neotropical			Nearctic		
	Families	Genera	Species	Families	Genera	Species	Families	Genera	Species	Families	Genera	Species	Families	Genera	Species	Families	Genera	Species
Pteropodidæ ...	—	—	—	1	3	18	1	5	20	1	7	33	—	—	—	—	—	—
Rhinolophidæ ...	1	2	5	1	3	11	1	3	28	1	3	6	—	—	—	-	—	—
Nycteridæ	-	—	—	1	2	8	1	2	3	—	—	—	—	—	—	—	—	—
Vespertilionidæ.	1	7	25	1	6	28	1	6	47	1	7	18	1	5	24	1	5	14
Emballonuridæ ..	1	2	2	1	5	18	1	5	13	1	4	7	1	8	26	1	1	1
Phyllostomidæ...	—	—	—	—	—	—	—	—	—	—	—	—	1	31	55	—	—	—
Total . . .	3	11	32	5	19	83	5	21	111	4	21	64	3	44	105	2	6	15

In considering the geographical distribution of each family of the Chiroptera and the range of its genera and species, I think it well to commence with the Vespertilionidæ and Emballonuridæ, as these alone are to any extent cosmopolitan in their distribution.

Of the sixteen genera of Vespertilionidæ five (*Antrozous*, *Nycticejus*, *Atalapha*, *Natalus* and *Thyroptera*), are peculiar to America, but these are represented by nine species only. Of the remaining eleven genera, eight are peculiar to the Eastern hemisphere, and of these *Nyctophilus* and *Chalinolobus* (subgen.) are limited to the Australian region; *Synotus*, *Otonycteris*, and *Plecotus* (subgen.) to the Palæarctic. A second species of *Plecotus* (the type of a well-defined subgenus *Corinorhinus*) is found in the Nearctic region only. Two genera alone, *Vesperugo* and *Vespertilio* are cosmopolitan; but of the fifty species of the former, eleven only inhabit America, and the few American species of the latter genus are closely related to one another. A single species of Vespertilionidæ—*Vesperugo serotinus*—is alone known with certainty to extend into both hemispheres, although it is probable that *V. abramus* and *V. borealis* may be found hereafter to have as wide a distribution.

Although the genera of Emballonuridæ are much more equally distributed in number between the two hemispheres, half of the whole being American, a single genus alone, *Nyctinomus*, is common to both, and it is worthy of note that, of the twenty-one species of this genus, four only inhabit America, and those are all closely related to one another, and very far removed from any of the Old World species. *Furia*, *Amorphochoilus*, *Rhynchonycteris*, *Saccopteryx*, *Diclidurus*, *Noctilio*, and *Molossus*, represented by twenty-six species, are peculiar to the Neotropical region, while the remaining genera with thirty-seven species are limited to the Eastern hemisphere. Of these *Mystacina* with a single species is found in New Zealand only. *Coleura* appears to be limited to East Africa and the Malagasy subregion, but the species from these subregions are very distinct. *Emballonura* extends from Madagascar to the Malay Archipelago, and throughout the larger islands of the Polynesian subregion, but has not been recorded from any part of the adjacent continents.

The Neotropical genera of this family are, on the whole, more closely related to each other than to any of the old world genera; nevertheless there are certain peculiar forms of limited distribution in the Eastern hemisphere, which seem to have their nearest allies among neotropical species. Thus, the very remarkable species, *Cheiromeles torquatus*, which has not been found beyond the Indo-Malayan subregion, appears to be

closely related to some of the species of the Neotropical genus *Molossus* than to any of the Old World forms; and the same remark applies to *Nyctinomus australis*, which is characteristic of the Australian region.

Although the Emballonuridæ have as wide an eastwardly and westwardly distribution as the Vespertilionidæ, yet they are far exceeded by the latter family in their northern and southern range. While the Vespertilionidæ extend in the Northern hemisphere as far as the isothermal of 32° Fahr. or thereabouts, the Emballonuridæ are rarely found north or south of the isothermal of 55°.

The Rhinolophidæ are limited to the Eastern hemisphere, and within these limits the species have much less extended bounds than even those of the preceding family. No species has as yet been recorded with certainty from the Polynesian subregion, from Tasmania, or from New Zealand. With the exception of *Rhinolophus ferrum-equinum*, which extends throughout the Ethiopian and warmer parts of the Palæarctic region, the species of this family inhabiting each of the zoological regions comprised within the area of its distribution are distinct and characteristic. No species of the subfamily *Phyllorhininæ* extends into the Palæarctic region; *Cœlops* is limited to the Oriental region, and *Rhinonycteris* to the Australian; these last two genera, however, include but a single species each. The very remarkable forms *Phyllorhina commersonii* and *Ph. cyclops* belong to the Ethiopian region, but the former species alone extends into the Malagasy subregion.

The Nycteridæ are limited to the Ethiopian and Oriental regions, one species only passing slightly beyond the limits of the latter region, and none have as yet been found in the Malagasy subregion of the former. The Ethiopian species of the genus *Megaderma* are more closely related to each other than to the Oriental species. The distribution of *Nycteris* is remarkable: six species are limited to the Ethopian region, the seventh is found in Java, and differs from all the rest in the large size of the second lower premolar.

The Phyllostomidæ present the only instance of a family of Chiroptera limited to a single zoological region. None of the species are known with certainty to inhabit permanently any of the countries beyond the recognized limits of the Neotropical region. This family is therefore eminently characteristic of that region. Although Central America and Southern Mexico have representatives of almost every genus of Phyllostomidæ, none of the species have been, with any certainty, recorded from the Southern States of North America, though the mean annual temperature of a great part of these countries equals or exceeds that of many parts of South America where representatives of the family are abundant. It is worthy of note that *Macrotus waterhousii*, which has been alone found as far north as Cape St. Lucas in California, is apparently omnivorous, living indifferently on fruit, insects, and probably on small bats; and *Trachyops cirrhosus* recorded doubtfully from South Carolina and from Bermuda, is evidently, judging from its structure, of the same habits. The power possessed by these species of varying their food evidently renders them more capable of extending their range beyond the limits of their original homes. Few, if any, of the species of this family, in the present state of our knowledge, can be said to be characteristic of any of the Neotropical subregions; but certain species appear to be limited in their distribution within the region.

The Megachiroptera, represented by the single family Pteropodidæ,

present probably more peculiarities in their distribution than any other group of Chiroptera. Like the Rhinolophidæ and Nycteridæ, they are strictly limited to the Old World, and scarcely extend anywhere beyond the tropics. Their limitation to the tropical parts is easily explained by a consideration of the fact that there only is found a continuous supply at all seasons of the tree-fruits on which they subsist; but this does not account for certain peculiarities in their distribution in an eastwardly or westwardly direction. While the family is distributed throughout the Ethiopian, Oriental, and Australian regions (except Tasmania and New Zealand), a single genus only, *Cynonycteris*, extends throughout all these regions. *Epomophorus*, which includes certain species so different from all other Megachiroptera, as to almost necessitate the formation of a distinct subfamily for their reception, is strictly limited to that part of the Ethiopian region included within the continent of Africa. *Cynopterus* is also limited to the Oriental region; a single anomalous species, *C. latidens* (which differs widely from all the other species in the form of its teeth) being found in the Moluccas. *Eonycteris* is, as yet, known from the Indo-Malayan subregion alone; *Notopteris* appears to be limited to the Polynesian subregion; *Harpyia* and *Cephalotes* are characteristic of the Austro-Malayan subregion.

The distribution of the genus *Pteropus* (which includes more than half the whole number of the species of *Pteropodidæ*) is more remarkable than that of any of the other genera of Chiroptera. The Comoro Islands in the Mozambique Channel form its westward limit, thence the species extend throughout the Malagasy subregion, even to the small hurricane-swept island of Rodriguez (from which I have lately described a new species), and northwards through the Amirantes and Seychelle Islands to India, where their westward limit is found at the southern frontier of Baluchistan: from India they extend eastwards throughout the Oriental and Australian regions (except Tasmania and New Zealand), inhabiting Polynesia as far eastwards as Samoa and Savage Island. Although one thousand miles of unbroken ocean divide the Seychelle Islands from the Chagos group (the nearest intermediate land to India), the Indian and Madagascar species (*Pteropus medius* and *Pt. edwardsii*) are very closely allied; while, on the other hand, not a single species crosses the narrow channel between the Great Comoro Island and the African coast, although certainly two species (*Pteropus edwardsii* and *Pt. livingstonii*), and probably a third (*Pt. vulgaris*), inhabit the Comoro group.

The following table exhibits the very remarkable distribution of the species of this genus:—

Regions	Subregions	Number of Species	Remarks
Ethiopian...	1. 2. 3. African	None	
	4. Malagasy	5	All these species very distinct.
Oriental ...	1. Hindostan........	1	Very closely allied to one of the Malagasy species.
	2. Ceylon		
	3. Indo-China	4	Three very closely allied.
	4. Indo-Malaya......	4	Three very closely allied.
Australian...	1. Austro-Malaya ...	15	All the species very distinct.
	2. Australia	5	
	3. Polynesia	5	
	4. New Zealand......	None	

TABLE SHOWING THE NUMBERS AND DISTRIBUTION OF THE PECULIAR GENERA AND SPECIES OF THE CHIROPTERA.

	Palæarctic				Ethiopian				Oriental				Australian				Neotropical				Nearctic			
	Genera	Percentage	Species	Percentage	Genera	Percentage	Species	Percentage	Genera	Percentage	Species	Percentage	Genera	Percentage	Species	Percentage	Genera	Percentage	Species	Percentage	Genera	Percentage	Species	Percentage
Pteropodidæ ...	—	—	—	—	1	33	18	100	2	40	18	90	4	57	31	90	—	—	—	—	—	—	—	—
Rhinolophidæ...	—	—	2	40	—	—	10	90	1	33	27	96	1	33	6	100	—	—	—	—	—	—	—	—
Nycteridæ	—	—	—	—	—	—	8	100	—	—	3	100	—	—	—	—	—	—	—	—	—	—	—	—
Vespertilionidæ.	2	28	11	44	—	—	24	85	—	—	34	72	—	—	13	72	2	40	20	83	1	20	10	71
Emballonuridæ.	—	—	—	—	1	20	16	88	1	20	11	84	1	25	7	100	6	75	25	96	—	—	—	—
Phyllostomidæ.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	31	100	55	100	—	—	—	—
Total.	2	28	13	42	2	26	76	92	4	31	88	93	6	38	57	90	39	71	100	93	1	20	10	71

From the table (p. 162) it may be observed, that of the 39 species, 30 (or nearly 80 per cent.) inhabit the Malagasy subregion, and the Australian region; and that more than 50 per cent. of the whole are found within the narrow limits of the Malagasy and Austro-Malayan subregions.

It is worthy of notice, that of the nine species inhabiting the Oriental region, three only can be considered very distinct, and these are closely related to some of the species from the Malagasy and Austro-Malayan subregions, so that it appears evident that the species now inhabiting the Oriental region, were derived at a comparatively recent period from the above-named subregions.

The sum of the foregoing remarks is well set forth in the second table (p. 163), which exhibits the number of peculiar genera and species of each and of all the families of Chiroptera in each zoological region, and also shows their percentage on the total number of the genera and species. This table also shows that among the Vespertilionidæ and Emballonuridæ only, which are cosmopolitan in their distribution, does the percentage of peculiar species in each zoological region fall below 90, while even in these families it is rarely as low as 70.

We may now proceed to consider to what extent the recognised zoological regions are severally characterised by the possession of peculiar families, genera, or species of Chiroptera.

In the first place, the two primary divisions of the earth, Palæogæa and Neogæa, are well characterised by their Chiropterous fauna: the former by the possession of three peculiar families, the Pteropodidæ, Rhinolophidæ, and Nycteridæ, and by the absence of the Phyllostomidæ; the latter by the absence of the three first-named families, and by the presence of the latter. Although the Vespertilionidæ and Emballonuridæ are common to both hemispheres, one species only is known with certainty to inhabit both the New and the Old World, and all the genera except three are peculiar.

The remarkable poverty of the Nearctic and Palæarctic regions in species, and especially in peculiar species, is well shown in the table. In the Nearctic region the number of peculiar species is but one-tenth of those which are characteristic of the closely connected Neotropical region; in the Palæarctic, one-sixth of those in the Ethiopian, and one-seventh of those in the Oriental region. Moreover, the few species which appear to be peculiar to these two regions do not present such marked differences in structure from the species of the adjoining regions as the peculiar species of other regions; in other words, they are not so characteristically peculiar. This taken into consideration with the comparatively large percentage of non-peculiar species which are found in these and in the adjoining regions, and which extend as a rule into the southern parts only of these regions, shows that the Chiropterous fauna of the Nearctic and Palæarctic regions is mainly, if not wholly, derivative.

This is precisely what we should have expected theoretically; for, knowing that the greater part of the Nearctic and Palæarctic regions was covered with ice at a comparatively recent period, and therefore uninhabitable by a class of animals few of which now extend even in summer as far as the limit of permanently frozen ground, we must suppose that on the cessation of the glacial epoch, these regions derived their Chiropterous fauna from countries lying south of them.

It appears evident, however, that the Nearctic region has derived many of its species from the Palæarctic, probably by way of Behring

Straits, at a time when more dry land existed in the northern parts of the Pacific Ocean. Although *Vesperugo serotinus* is the only species known with certainty to extend from the Palæarctic to the Nearctic region, yet so close is the connection between many other Palæarctic and Nearctic species (between *Vespertilio mystacinus* and *V. nitidus*, *Vesperugo abramus* and *V. hesperus*, *Vesperugo borealis* and *V. propinquus*, *e.g.*), that it is not necessary to require long separation to account for the few specific differences now noticeable.

Of the eleven species which appear to be peculiar to the Palæarctic region, both the species of Rhinolophidæ are evidently very closely related to Ethiopian forms; and the Vespertilionidæ, with the exception of *Plecotus auritus*, and *Synotus barbastellus*, are also represented by nearly allied forms in either the Ethiopian or Oriental regions.

The Nearctic and Palæarctic regions are therefore more characterised, so far as their Chiropterous fauna, by the absence rather than by the presence of peculiar genera and species.

The remaining four regions, however, present a remarkable contrast in this respect. Each region appears to be as well characterised by its Chiroptera as by any other order of Mammalia.

This is especially noticeable in the Neotropical region, which possesses a very remarkable family, the Phyllostomidæ, nowhere represented beyond its limits; also six peculiar genera of Emballonuridæ (amounting to 75 per cent. of the genera of that family); and two of Vespertilionidæ, making in all 39 genera peculiar to this region.

The Ethiopian region (excluding Madagascar and its islands) is characterised by that very remarkable genus of Pteropodidæ, *Epomophorus*, which stands so far apart from all other genera of this family; also by 71 species of other genera, of which more than 90 per cent. are peculiar.

Madagascar and adjoining islands, included by Mr. Wallace under the name of the Malagasy subregion, although possessing some species (*Phyllorhina commersonii*, *Nyctinomus acetabulosus*, *Taphozous mauritianus*, *Vesperugo minutus*, *e.g.*) which are also found on the African continent, has other species representing a genus of which the remaining representatives are found in far distant continents. Thus, as I have remarked when treating of the distribution of the Pteropodidæ, the genus *Pteropus* is well represented in Madagascar and adjoining islands, and in the Oriental and Australian regions as far as the Navigator's Islands, although not a single species extends into the continent of Africa. This genus includes by far the largest and most highly organised species of Chiroptera, which in number also amount to more than one-tenth of the whole order; and their remarkable distribution can only be accounted for by adopting the hypothesis of the existence at a comparatively recent date of a continent, or, more probably, of an archipelago of very closely connected islands, in the wide space of ocean now separating Madagascar from India and Australia. It is inconceivable that species to which a narrow channel of less than 200 miles suffices to act as an effectual barrier, could traverse thousands of miles of unbroken ocean in other directions.

Even if we suppose that their presence in Africa is prevented by some cause unknown to us, still it is difficult to imagine species so slow in their flight as those of this genus crossing a channel of even half the width of that separating the Comoro Islands from the coast of Africa. But *Pteropus medius* of India is so closely related to *Pt. edwardsii* of Mada-

gascar, that by many zoologists it would most probably be considered a variety only of the former species—a variety, it is quite conceivable, which might result from separation in a comparatively very short period.

The Malagasy subregion also possesses four other species of *Pteropus* all very distinct from each other, having their nearest allies in the Australian region. One of these species, *Pt. rodricensis*, recently described by me, inhabits the small wind-swept island of Rodriguez, where its means of subsistence must now be very limited. It is difficult to account for the presence of such large and highly-organised species in these small islands, except on the supposition that the islands were not only much larger at some former time, but were also, as I have already remarked, closely connected with a chain of slightly separated islands, uniting them with the Indian and Australian continents.

The Oriental region falls very slightly short of the Ethiopian in the percentage of its peculiar species, and slightly exceeds it in genera. Of 110 species eighty-eight are peculiar; of these eight only are also found in the Ethiopian region, and they also extend into the Palæarctic. The genera *Cynopterus*, *Eonycteris*, *Cœlops*, and *Cheiromeles* are characteristic, but the latter three are each represented by a single species only. Of the remaining seventeen genera, two, *Pteropus* and *Emballonura*, are also common to the Malagasy subregion and to the Australian region, and ten are also found in the Oriental and Australian regions. With the exception of such cosmopolitan species as *Miniopterus schreibersii* and *Vesperugo abramus*, the Oriental species extending into the Australian region appear to inhabit only the adjacent parts of that region. The distinctiveness of the Oriental and Australian Chiropterous faunas is well shown by a collection made lately in Duke of York Island and New Ireland, in which, out of twelve species, two only are also known from the Oriental region.

The Australian region comes next to the Neotropical in the number of its peculiar genera; of the twenty-one known, six are peculiar, and of these four belong to the Pteropodidæ, being nearly half the whole number of the genera of that family. This region may therefore be considered the cradle of the Megachiroptera, although the total number of all species falls far short of either that of the Ethiopian or of the Oriental region, yet in the percentage of peculiar forms it holds an intermediate place.

Two of the Australian subregions, the Austro-Malayan and the New Zealand, claim particular attention, the former for the great number of its species, the latter for the opposite reason. Of sixty-four Australian species, fifty-seven are peculiar, and of these nearly half appear to be limited to the Austro-Malayan subregion; while two species only, of which one is peculiar, inhabit New Zealand.

Great Britain, which nearly equals New Zealand in extent, has eight times the number of its species; and Madagascar, which is alone comparable with it in peculiarity of fauna, exceeds it almost in the same proportion.

The poverty of this subregion in species is, therefore, unequalled, and undoubtedly depends to a great extent, if not altogether, on the comparative absence of insects, and probably especially of those species on which bats prey. The peculiar structure of *Mystacina tuberculata** appears to indicate that this species seeks its food among the branches and leaves of trees on which Longicorn Coleoptera, which are most abundant among

* See my paper on this species in P. Z. S., 1876, p. 486.

the New Zealand insects, feed. This remarkable species of Emballonuridæ constitutes a distinct group of that family, but has its nearest allies in the species of the group Molossi. Its fancied relationship to the Phyllostomidæ of the Neotropical region (as set forth by Mr. R. F. Tomes) is altogether illusory, as it depends only on the agreement between it and the species of that family in possessing a third phalanx in the index finger, which is related, as I have shown,* to the peculiar manner in which the wing is folded in repose, and occurs not only in this species, but also in some of the larger species of Molossi.

A review of the above-stated facts shows:—

1. That the Chiroptera, though possessing exceptional powers of locomotion, and therefore of dispersal, appear to be almost as strictly limited by certain barriers as other orders of Mammalia.

2. That while the geographical distribution of the families, genera, and species of this order on the whole adds further remarkable confirmation of the accuracy of the division of the earth into six zoological regions as defined by Mr. Sclater and subsequently adopted by Mr. Wallace, the peculiar distribution of the most highly organised and distinct, as well as of the largest genus, namely, *Pteropus*, adds additional strength to the views of those who, in consideration of the very peculiar nature of the fauna of Madagascar, feel disposed to form with it and the adjoining islands a seventh zoological region, to which Mr. Sclater's name "Lemuria" has been applied.

On Recent Improvements in the Port of Dublin. *By* BINDON B. STONEY, *M.A., M.R.I.A., M. Inst. C.E., Engineer of the Dublin Port and Docks Board.*

[PLATES I., II., AND III.]

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

THE trade of few harbours in the United Kingdom has made greater relative progress within the last twenty years than that of Dublin. This, no doubt, is mainly due to the increased prosperity of the country as a whole, but it may also be attributed in great measure to the convergence of the main lines of internal traffic to Dublin, which has thus naturally become more and more the mart and emporium for a great portion of Ireland. During this period of twenty years the tonnage entering the port has much more than doubled. In 1857 it amounted to 880,844 tons, and last year it rose to 1,973,781 tons, while during the current year there is a good promise that it will surpass the 2,000,000 limit. For the sake of comparison I have placed in a tabular form the tonnage of Liverpool and Glasgow, as well as those of the three principal ports in Ireland, for the three years preceding 1858 and 1878 respectively, so as to give fair averages of their respective rates of progress within the last twenty years.

From this table it will be observed that while the tonnages of Liverpool and Glasgow have respectively increased fifty per cent. in the last

* P. Z. S., *l. c.*

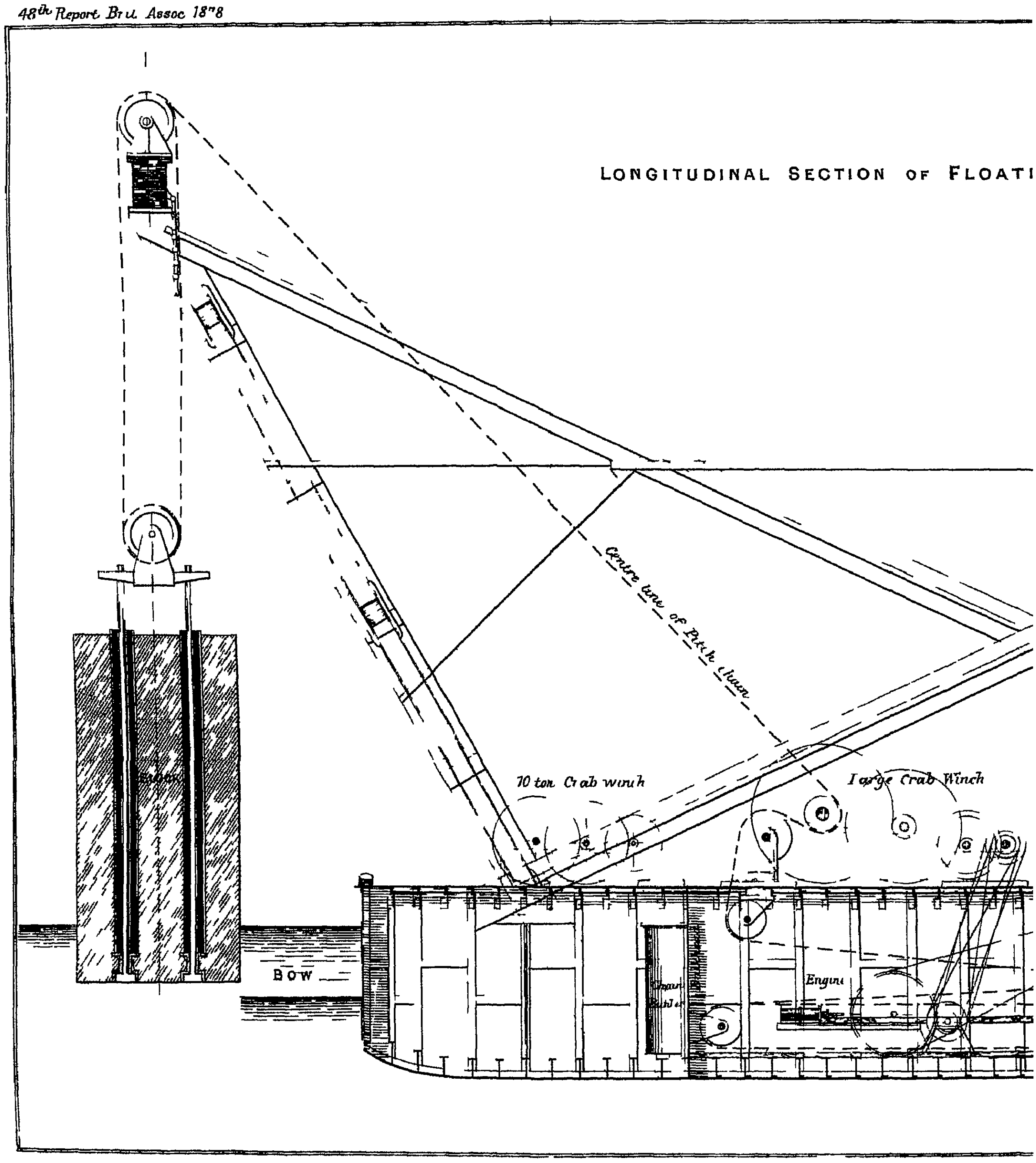
twenty years, those of Belfast and Cork have nearly doubled, and that of Dublin has considerably more than doubled in the same time. Also, the tonnage of Glasgow is only one-fourth more and that of Liverpool is not four times greater than that of Dublin.

	Liverpool (including Birkenhead)	Glasgow	Dublin	Belfast	Cork *
	Tons	Tons	Tons	Tons	Tons
1855	4,096,160	1,666,518	882,719	744,364	328,658
1856	4,320,618	1,673,096	904,903	772,127	347,126
1857	4,645,362	1,612,681	880,844	796,968	384,167
Average of preceding 3 years	**4,354,047**	**1,650,765**	**889,488**	**771,153**	**353,317**
1875	6,588,731	2,249,857	1,677,543	1,434,754	623,463
1876	6,805,970	2,298,076	1,879,886	1,497,585	740,558
1877	7,000,726	2,428,616	1,973,781	1,566,752	740,201
Average of preceding 3 years	**6,798,476**	**2,325,516**	**1,843,737**	**1,499,697**	**701,407**

The increase in the tonnage of the Port of Dublin is not confined to one class of vessel alone; for we find that while the coasting trade increased from 821,640 tons to 1,543,861 tons, or nearly doubled in the last twenty years, the oversea trade increased from 67,848 tons to 299,876 tons, or more than quadrupled in the same period. Previous to 1865 the shipping quays of Dublin were, with the exception of a short length opposite the Custom House, founded at or close to low water level, and when the tide was out the foreshore used to strip out a long way in front of the walls. To meet the demand for a greater depth than this, timber jetties had been from time to time constructed along portions of the North Wall, so as to give about 8 feet at low water in line of keel; and for many years this expedient was found to answer for the cross-channel steam trade and for a few of the smaller oversea vessels, while the larger vessels of the latter class either discharged in Kingstown Harbour, or in a small excavation called Halpin's Pool, which had been dredged in the open harbour beyond the end of the North Wall. The first real attempt at providing deep water quays was commenced in 1864 by rebuilding nearly 700 feet in length of the east end of the North Wall quay, so as to allow vessels drawing 17 feet to lie afloat alongside at low water; but the most important improvements of this kind were not commenced till 1870, since which date 6500 feet of quay have either been rebuilt or constructed where no quays existed before, so as to give depths of from 15 to 24 feet at low water, and enable the cross-channel steamers to sail at fixed hours independently of the tide, as well as allow the larger class of oversea vessels which now frequent the port to lie always afloat. It will be observed that the rebuilding of the former quay walls at a greater depth did not add to their length, though it enabled rather more vessels than formerly to be accommodated in a given length of wall, and the extending commerce of the port rendered it necessary to provide additional deep water accommodation to suit the oversea trade, which, as already observed, has increased more than four-

* The tonnage of Cork Harbour is exclusive of vessels calling for orders, mails, or passengers, and not loading or unloading cargo.

48th Report Brit. Assoc. 1878



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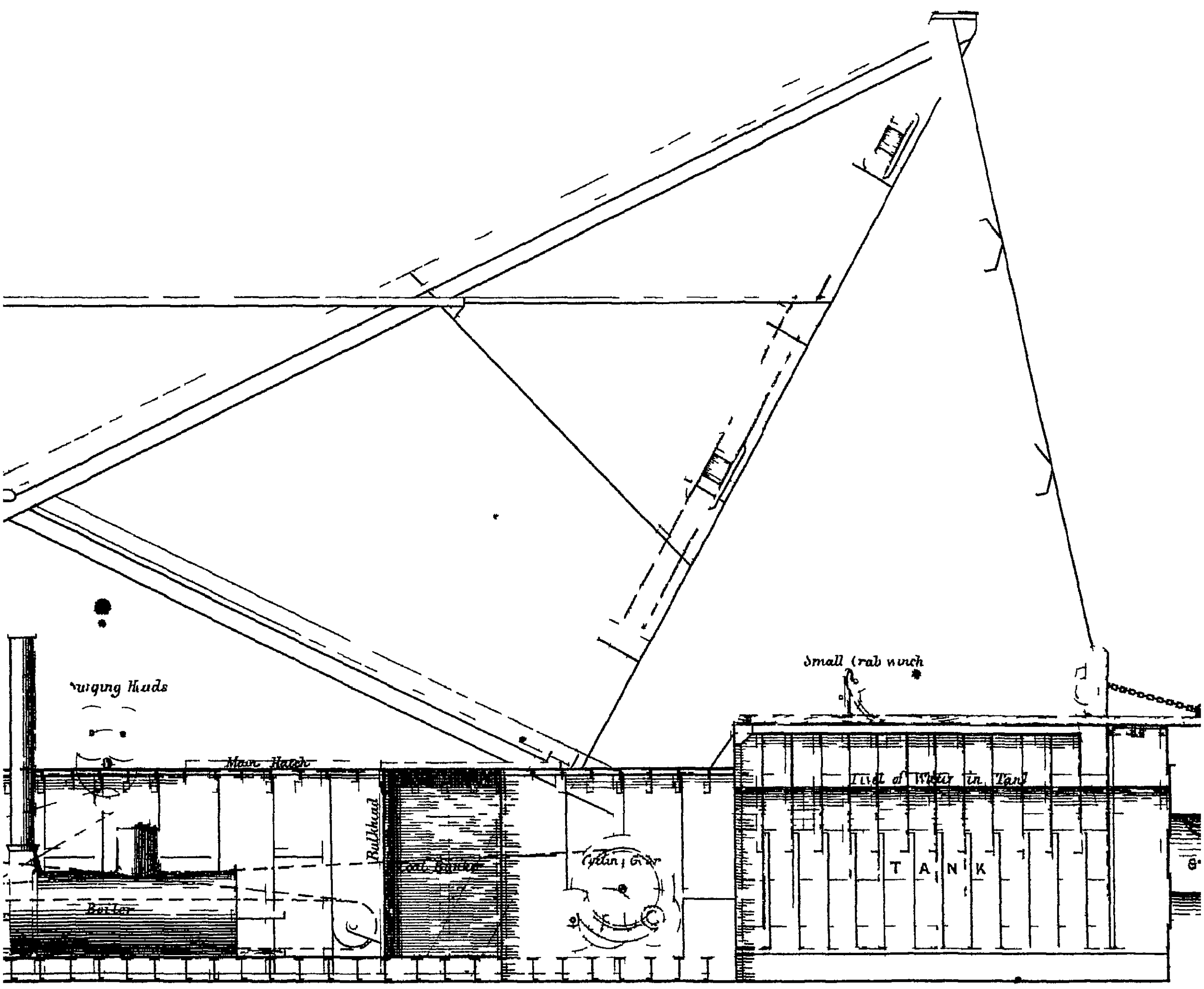

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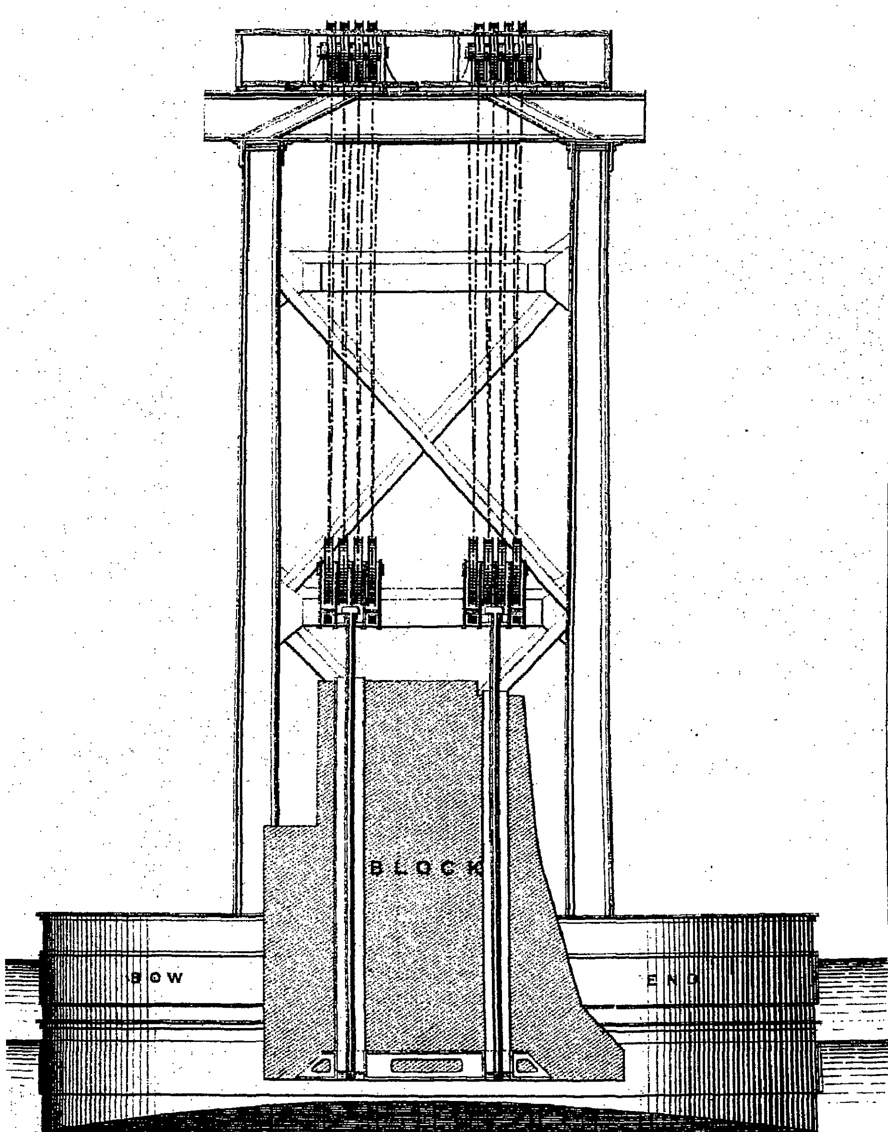

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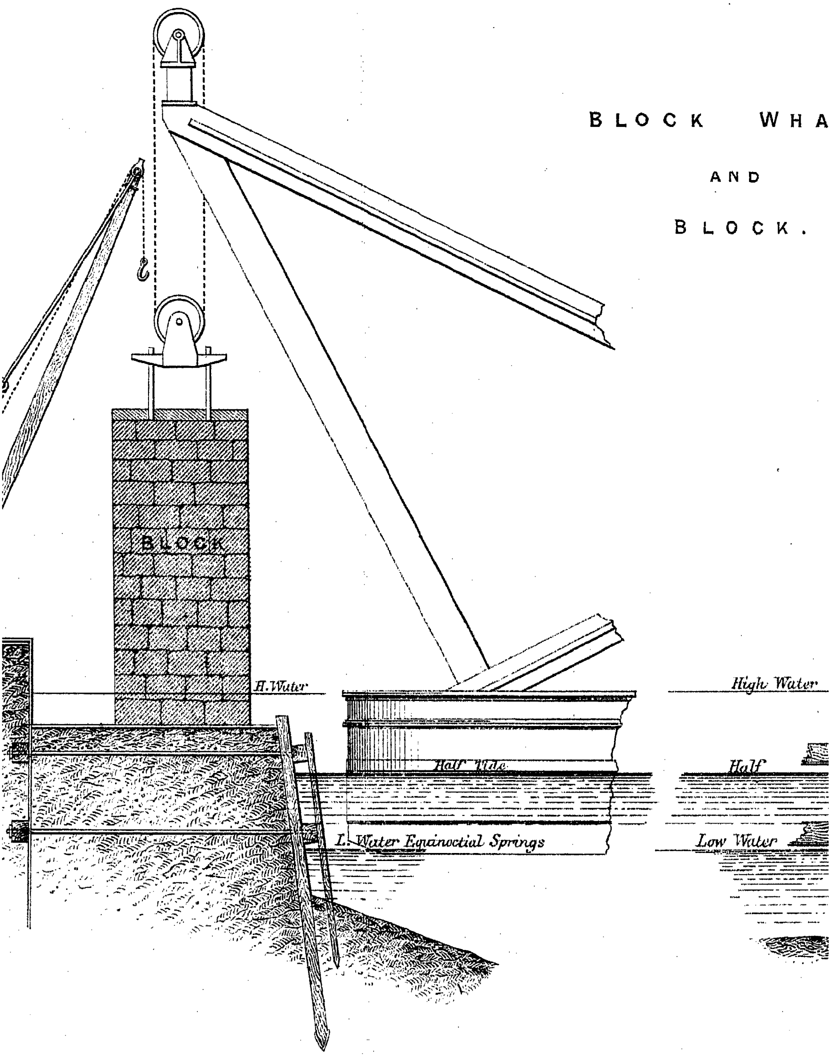

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Illustrating Mr. B. B. Stoney's Paper on Recent Improve

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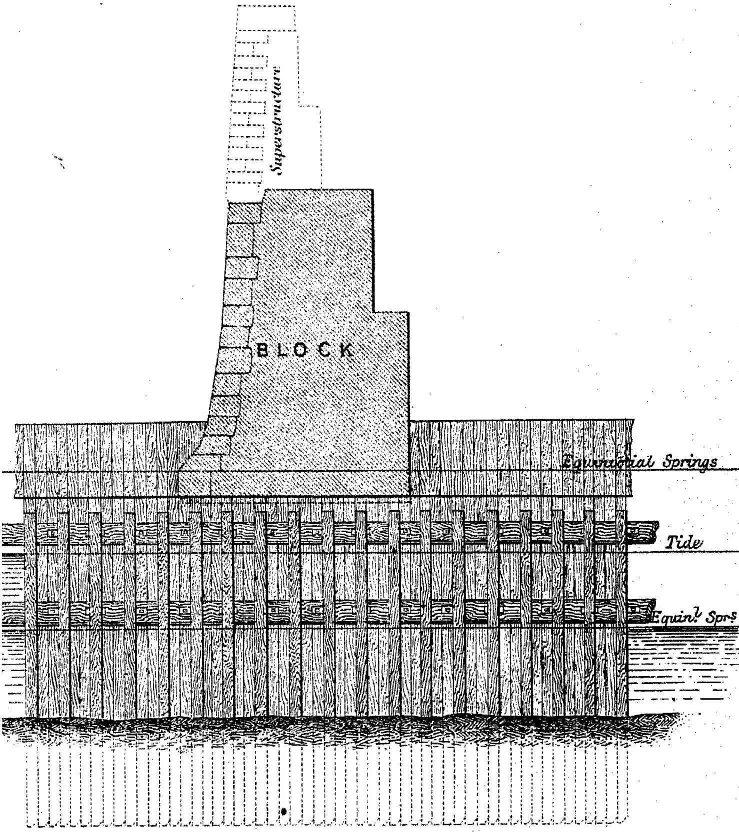

FRONT ELEVATION OF WHARF & CROSS SECTION OF BLOCK.

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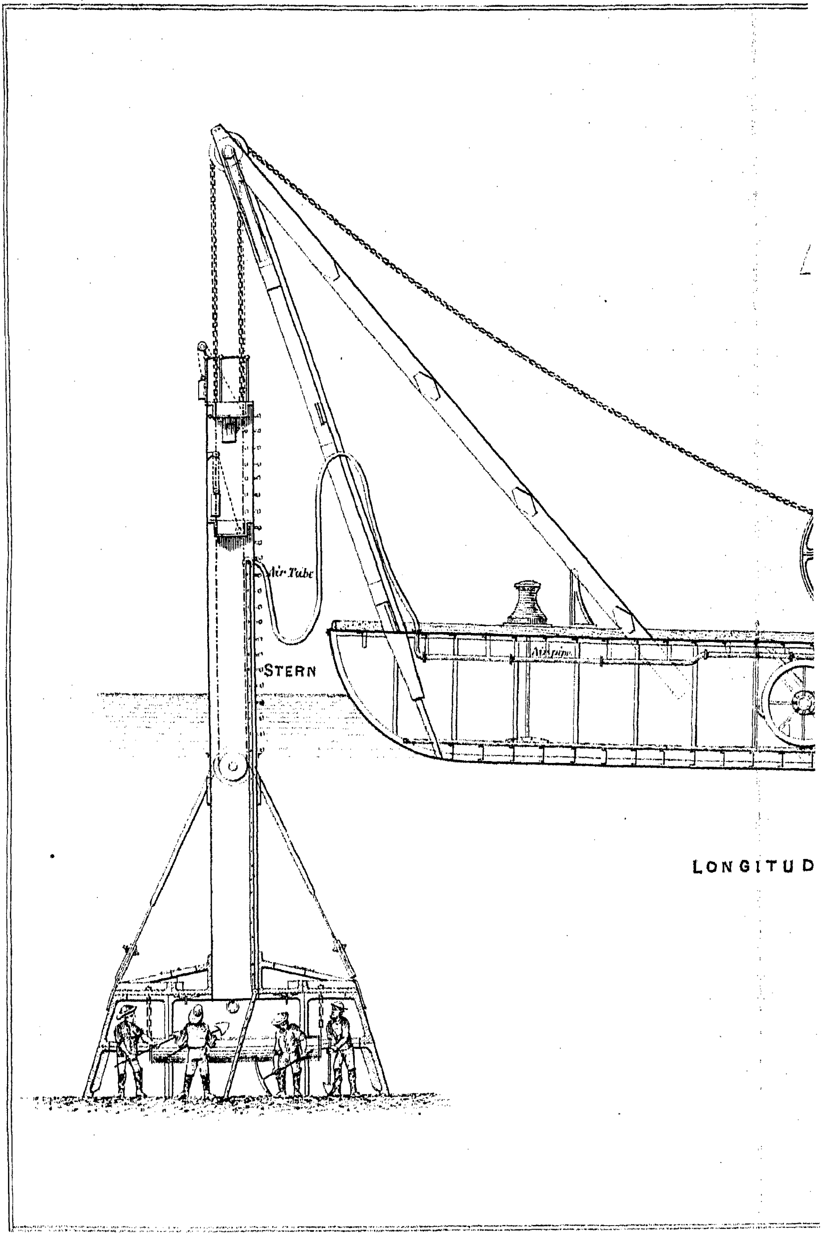
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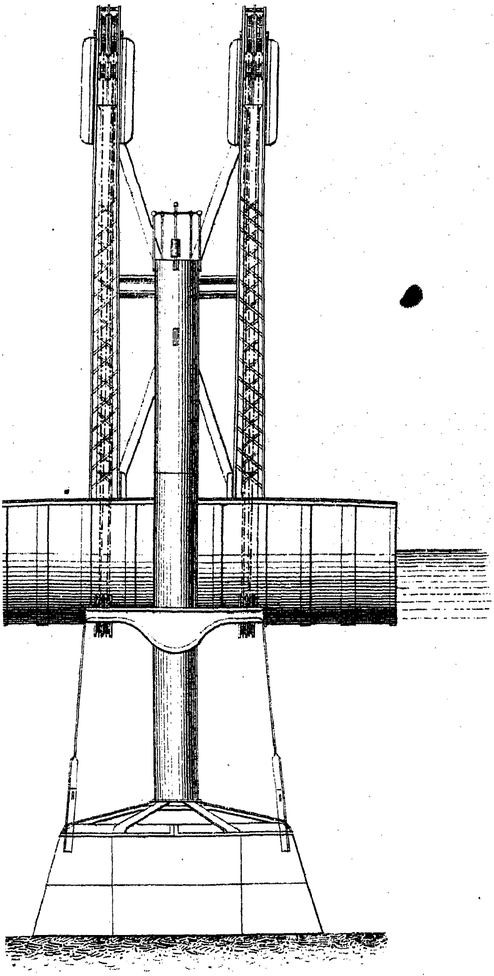


END ELEVATION.

Spottiswoode & Co Lith. London.

fold in the space of twenty years. Accordingly it was determined, after mature consideration, to extend the North Wall, and construct a large tidal basin with 24 feet at low water inside and 22 feet along the river face, so as to float the largest commercial vessels at all states of tides. The masonry was commenced in 1871, and up to the present about 2500 lineal feet of wall have been built on a novel principle which avoids the trouble and expense of cofferdams, pumping, staging and other temporary works, the expenditure on which frequently exceeds the cost of the permanent work to which they are merely ancillary. The new mode of construction consists in the use of blocks of masonry of unprecedented size in the foundations below low water level, as represented in the diagrams which accompany this paper. Each block is 29 feet high, $11\frac{1}{2}$ feet long, and 21 feet 4 inches broad at the base, and weighs 350 tons; they are built on land on a block wharf (Plate II.), and about three months after completion they are lifted by a powerful floating shears (Plate I.), and conveyed to their destination in the quay where each block forms $11\frac{1}{2}$ feet in length of the lower portion of the wall as far as low water level, and when a number of these blocks have been thus laid in position the superstructure up to the coping level is built over them in the usual manner by tidal work, the total height of the wall being 45 feet. Besides the large floating shears for lifting and moving the blocks about, there is one other special appliance—namely, a diving bell (Plate III.), also of unprecedented size and peculiar in construction. This bell, which weighs 80 tons, is used for excavating and levelling the river bed on which the blocks lie. The chamber is cast-iron, 20 feet square and $6\frac{1}{2}$ feet high, with a tube or funnel 3 feet in diameter, and rising to a height of 44 feet over the bottom of the bell; and this is the greatest depth of water for which the present bell is intended, though by adding to the length of the funnel it might be worked in greater depths. The upper end of the funnel forms an air lock $6\frac{1}{2}$ feet high, with double doors and suitable cocks for admitting the compressed air from the chamber into the lock, or for letting that in the lock escape into the external atmosphere, and by this arrangement the workmen can pass up and down without lifting the bell off the bottom or stopping the work of excavation. Inside the chamber are two large iron trays, and the men shovel the excavated earth into these trays. When they are filled the bell is lifted a few feet off the ground, and the barge hauled some yards to the rear of the wall where the trays are discharged, by pulling out a detent, and the barge is then brought back to its working position, and the bell lowered as before.

The operation of lifting and setting a block is as follows:—The floating shears is brought bow-on to the block wharf during flood tide, and the lifting chains are attached to iron suspending bars which pass through each block. The chains are then hauled in by the winches on board, and water is pumped into a large tank at the after-end of the vessel to counterbalance the weight of the block, which is then floated away to its destination and lowered into place the following low water, so that at one step $11\frac{1}{2}$ feet forward of wall are built up to low water level.

The cost of both floating shears and diving bell was under 25,000*l.*, and the whole of this was repaid in the first 600 feet of wall by the superior economy of this system over ordinary cofferdam and pumping work, and the relative saving now amounts to about 16,000*l.* per annum.

It would obviously be useless to construct deep water quays if the

river channel and bar were not also deepened to correspond. Sixty years since the depth of water on Dublin bar was about 6 feet; indeed, there was, a few years ago, an old man in the harbour employment who had in his youth stood on the bar at a good low water. At this time the North Bull Wall did not exist, and the bar, consisting of hard sand, extended in a curved direction about half a mile east of Poolbeg Lighthouse. As soon, however, as the Bull Wall was built, the large volume of water flowing and ebbing over the 2500 acres which were enclosed between it and the Pigeon House Wall, was confined in direction and augmented in velocity, so that it impinged against the bar and scoured it away to its present depth of about 16 feet at low water, giving a depth of 28 feet at high water springs, and this is still gradually improving; for 20 years since there was 3 feet less than at present, and it is believed that there is no other instance on record of a bar being so successfully deepened by artificial means. The depth in the river channel has recently made great progress, corresponding to the other improvements in the port. The average tonnage dredged in each of the ten years preceding 1860 did not reach 150,000 tons, and it is now close on a million tons per annum. The greater portion of this dredged material is now conveyed to sea in very large hopper barges, each of which carries 850 to 1000 tons, according to the state of the weather, to a distance of 8 miles from Dublin, or about 2 miles beyond the Bailey Lighthouse, where it is deposited in deep water beyond the influence of tides within the bay. Very great economy has resulted from this system of large hopper barges as compared with the older methods; for, multiplying the present tonnage dredged by the saving per ton, the gross saving amounts to considerably over 40,000*l.* per annum. Indeed, without this economy it would have been impossible to carry out the other improvements in the port; for Dublin, though one of the larger ports in the kingdom, has relatively the smallest income, as there are no dues on goods except some small ones on timber, bricks and marble, which in the aggregate do not reach 2000*l.* annually. This will appear at a glance from the following table, which gives the revenue derived by the ports already mentioned from tonnage dues and dues on goods for the year 1877, and also the income which each ton yields the several ports as well as their respective debts.

Port	Tonnage Rates	Rates on Goods	Total	Registered Tonnage	Income per Ton Register	Debt
	£	£	£	Tons	Pence	£
Liverpool	377,612	599,024	976,636	7,000,726	**33·5**	15,249,290
Glasgow	45,253	123,147	168,400	2,428,616	**16·64**	3,211,383
Dublin	58,451	1,799	60,250	1,973,781	**7·32**	330,734
Belfast	41,275	37,630	78,905	1,566,752	**12·1**	716,708
Cork	13,432	18,306	31,738	740,201	**10·3**	103,885

The rates on goods for Liverpool include the so-called "Town dues" on goods, amounting to 263,329*l.*; but as these were purchased by the Mersey Docks and Harbour Board from the Corporation of Liverpool in 1857 for their then estimated value of a million and a half sterling, they now form a very valuable portion of the port revenues.

The tonnage rates for Cork include 3791*l.* derived from one halfpenny per ton levied on vessels using or entering the harbour as a port of call, but not loading or unloading cargo therein. It represents a tonnage of 1,819,860 tons, and is quite distinct from the 740,201 tons which represents vessels loading or unloading cargo; but, as it is available for port purposes, it is included in the tonnage rates of Cork harbour, in the second column above. If this were omitted, the income would be reduced to 9*d.* per ton register.

This table shows that for every ton entering their respective ports, Liverpool receives more than four and a half times and Glasgow more than twice the revenue that Dublin gets, while Belfast gets two-thirds more, and Cork nearly fifty per cent. more.

The floating shears and diving bell are useful for many other purposes besides building quay walls. Among others they are well adapted for breakwater construction and laying the foundations of beacons and lighthouses in suitable localities. There is at present a lighthouse in process of construction at the extremity of the Bull Wall which forms the north side of the entrance to Dublin Harbour, the foundations of which in such an exposed place would have been very costly if built by any of the ordinary methods. The base is formed of two large semicircular blocks, each sixteen feet high, and together forming a circle of thirty feet in diameter and weighing nearly 700 tons. These blocks were built on the block wharf and conveyed about three miles down the harbour, where they were laid at a depth of several feet below equinoctial low waters on the rubble stone forming the extremity of the Bull Wall which had been previously excavated by the diving bell. On top of these blocks is built in heavy granite ashlar with solid rubble hearting the lower part, or what may be called the plinth of the tower, rising some feet over high water, and on top of this again the shaft of the tower is in process of construction, formed of wrought iron lined with timber, the total height from foundation to top of lantern being 79 feet. Opposite this lighthouse, and at the south side of the harbour entrance, stands Poolbeg Lighthouse, erected in the last century at the extremity of the pier beyond the Pigeon House Fort. The foundations of this latter lighthouse were laid at about low water level in the centre of a mound of rubble stone, and it was originally surrounded by a handsome cut stone platform, which was heavy enough to stand ordinary rough weather, but which, with the rubble stone on which it was laid, was constantly washed away by heavy storms from the sea front of the lighthouse, leaving the base of the latter exposed and liable to be undermined, and causing heavy annual expense from hauling the rubble back again, to be again scattered in the next gale. The lighthouse base and foreshore are now protected by large blocks weighing 140 tons each, two of which were carried at a trip by the floating shears and dropped on the irregular foreshore in front of the lighthouse, which they now protect from the violence of the sea which breaks on them before reaching the lighthouse. This work was exposed to the full brunt of the great storm of January 3rd, 1877, which nearly cut across the east pier of Howth Harbour and did considerable damage to the paved slope of Kingstown West Pier, and to the railways both at Monkstown and at Howth, which, strange to say, were apparently completely covered by their respective piers. The big blocks, however, protected the base of Poolbeg Lighthouse, and no damage whatever occurred to it. Besides excavating, the diving bell has been used for removing portions of wreck

and pulling up pile stumps in deep water, in which latter operation it is very successful, and three or four pile stumps can be drawn at one effort by attaching chains hanging from the ceiling of the bell chamber to the heads of the piles, and then raising the pile by its hoisting chains, which have a surplus working strength of about seventy tons when the bell is under water.

Report of the Committee, consisting of Professor CAYLEY, *F.R.S.*, Professor G. G. STOKES, *F.R.S.*, Professor H. J. S. SMITH, *F.R.S.*, Professor Sir WILLIAM THOMSON, *F.R.S.*, Mr. JAMES GLAISHER, *F.R.S., and* Mr. J. W. L. GLAISHER, *F.R.S.* (*Secretary*), *on Mathematical Tables.*

[PLATE IV.]

Account of the Calculation of the Factor Table for the Fourth Million.

A DESCRIPTION of the different factor tables that have been published is given in the British Association Report, 1873, pp. 34–40; and a more complete historical account of factor tables, especially of Felkel's and the manuscript tables of the last century is contained in the 'Proceedings of the Cambridge Philosophical Society,' vol. iii. part iv. pp. 99–138, 1878. It is only necessary, therefore, to give a brief notice of the extensive tables that have been published during the present century, and which it is the object of the Committee to complete.

These tables are:—

(1). Chernac's *Cribrum Arithmeticum*, which gives all factors of all numbers not divisible by 2, 3, or 5 from 1 to 1,000,000.

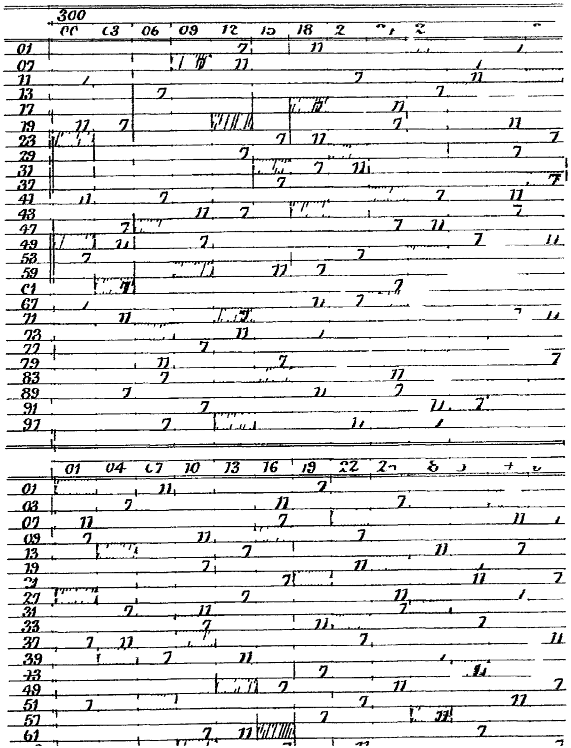
(2). Burckhardt's *Table des Diviseurs*, which gives the least factor of all numbers not divisible by 2, 3, or 5 from 1 to 3,036,000.

(3). Dase's *Factoren Tafeln*, which give the least factor of all numbers not divisible by 2, 3, or 5 from 6,000,000 to 9,000,000.

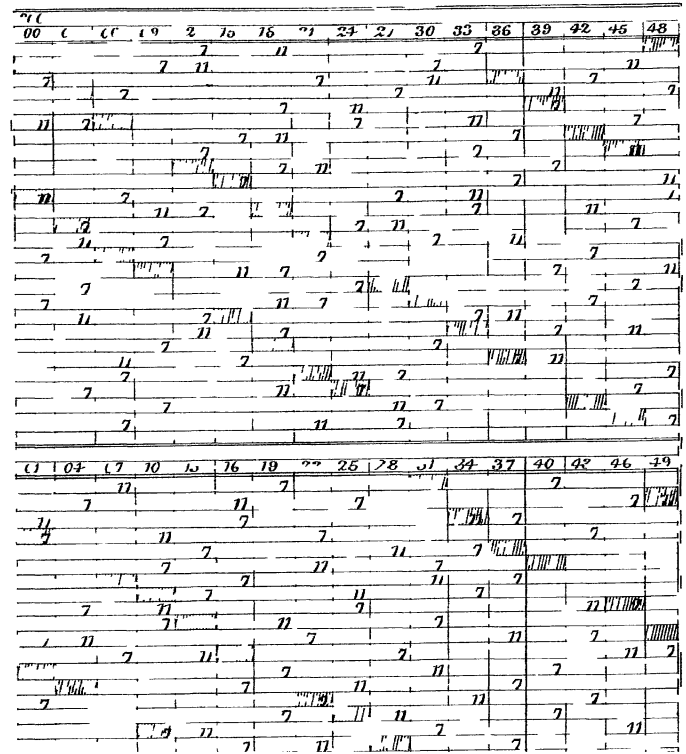
The reason of the gap between 3,036,000 and 6,000,000 is as follows: —Burckhardt completed the publication of his three millions in 1817, and some time previous so 1849 Crelle presented to the Berlin Academy the manuscript of the factor tables for the fourth, fifth, and sixth millions. In 1850 Gauss urged Dase to calculate factor tables for the seventh, eighth, ninth, and tenth millions, as the three intermediate millions were in the possession of the Berlin Academy, and he did not doubt that sooner or later they would be published. In 1860, through the support of friends in his native town, Hamburg, Dase, who was distinguished for his ability in calculation, was enabled to devote himself wholly to the carrying out of Gauss's project. On September 11th, 1861, he died suddenly, leaving the seventh million complete and the eighth million nearly complete; he had also determined a great number of the factors for the ninth and tenth millions. Dr. Rosenberg, of Hamburg, undertook the continuation of the work, and the seventh million was published at Hamburg in 1862, the eighth in 1863, and the ninth in 1865. In the preface to the ninth million it is stated that the tenth million was near completion. There was thus left

Diagram illustrating the mode of formation of the Factor Table for the Fourth Million

13



17



a gap of three millions between the third and seventh millions, which it was very desirable to fill up not only for the sake of completing the table up to nine millions, but also in order to render more useful the millions already published. Accordingly, Professor Cayley, the chairman of the Committee, wrote to Professor Kummer, the secretary of the Mathematical Section of the Berlin Academy, asking if there were any chance of the publication of the manuscript; and Professor Kummer, in a letter dated April 29th, 1877, replied that it had been examined on a former occasion, and found to be so inaccurate that "the Academy was convinced that the publication would never be advisable." The calculation was then at once commenced by Mr. James Glaisher, with the assistance of two computers, and has been continued without interruption since. The fourth million is completed and ready for press, and some progress has been made with the fifth and sixth millions, which are being calculated together, and which will be completed, it is believed, by the meeting of the Association at Sheffield. The tenth million has not been published. It remained in the possession of the widow of Dr. Rosenberg till the early part of the present year, when it was presented by her to the Berlin Academy.

The method employed in the calculation of the fourth million, and by which the fifth and sixth millions are being calculated, is practically the same as that which was invented by Burckhardt, and was adopted by Dase. As the method is a very remarkable one, and as no description of it (with the exception of a brief notice by Burckhardt himself) has been published, the following account of it is given here:—

A form was lithographed (Plate IV.), having 78 vertical lines and 81 horizontal lines (besides several other lines used for headings, &c.); it is thus divided into 77 × 80 oblong spaces which may for convenience be called squares. The eighty rows are numbered, at the extreme left of the sheet, 01,07 ..97; 01,03 . 99; 03,09,...99; there being two white spaces separating the hundreds. This is the same as in Burckhardt's or Dase's tables, each column representing 300 numbers. The advantage of having 77 columns is that the 7's and 11's are *lithographed* on the form and have not to be determined and inserted by hand. Thus if 77 consecutive columns of Burckhardt's tables be taken, and all the headings and tabular results except 7's and 11's be supposed to be removed, we have a representation of the form. The form actually used was constructed to begin from 3,000,000, so that for the exact representation of it we are to commence with the column headed 201 on p. 3 of Burckhardt's table (*i.e.*, the 68th column).

Since each sheet corresponds to 77 × 300 numbers, a million occupies about $43\frac{3}{10}$ sheets, and as on each sheet the number of 7's lithographed is 880, and the number of 11's is 480, it follows that, by adopting a form which permits the 7's and 11's to be lithographed, about 59,000 entries are saved in each million; and, what is even more important, the accuracy of these 59,000 tabular results is assured.

The squares to which the least factor 13 belongs were obtained as follows: Find the numbers between 3,000,000 and 3,000,000 + 13 × 300, which are divisible by 13, but not by 2, 3, or 5. Take 13 consecutive columns of any blank form and cut them off from the rest of the form; then, supposing the first column to correspond to the column headed 3,000,000, make a mark in the squares that correspond to the multiples of 13, previously found, and cut out the squares so marked. We thus have a group of 13 columns, from which a number of squares (80) have been

removed, and which may be called a screen or sieve. Place the sieve over the first 13 columns of the first sheet of the fourth million; then either empty squares or squares containing a 7 or 11 will appear through the holes of the sieve; in each empty square write the number 13. Then place the sieve over the next 13 columns and proceed as before, and so on throughout the whole 44 sheets.

The sieve for the next prime, 17, contains 17 columns, and is made in the same way, viz., by cutting out the squares corresponding to the numbers between 3,000,000 and 3,000,000 + 17 × 300, which are divisible by 17, and not by 2, 3, or 5. Then this sieve is placed over the first 17 columns, and 17 entered in all the empty squares, then placed over the next 17, &c., and so on.

The sieves for 13 and 17 are drawn in the plate (Plate IV.), the shaded squares being those that are cut out. The 13-sieve is formed of the first thirteen columns of one of the sheets, and the margin, containing the figures 01,07,..., is retained in order to show the arrangement of the form, which contains 77 columns. Of course in using the sieve this margin is cut off as in the 17-sieve. The 13-sieve shows the numbers between 3,000,000 and 3,000,000 + 13 × 300 which have least factors 7, 11, or 13; thus, for example, from the third column we see that

3,000,613	3,000,739	3,000,823
3,000,641	3,000,767	3,000,851
3,000,683	3,000,781	3,000,893
3,000,697	3,000,809	

have 7 as their least factor; that

3,000,679	3,000,811	3,000,877
3,000,701	3,000,833	3,000,899

have 11 as their least factor, and that

3,000,647	3,000,751	3,000,829
3,000,673	3,000,803	3,000,881

have 13 as their least factor. Of course the numbers such as 3,000,179, for which 7 appears in a shaded square, have 7 as their least factor, and are also divisible by 13; and similarly, when 11 appears in a shaded square, the number has 11 for its least factor and is also divisible by 13.

The 80 argument numbers 01, 07,...97; 01, 03,...99; 03, 09,...99 correspond to the 80 numbers 1, 7,...97; 101, 103,...199; 203, 209,...299 that remain when the numbers divisible by 2, 3, or 5 are thrown out from the 300 numbers 1, 2, 3, 4,...300. The numbers 01, 03... at the side are lithographed on the form, but the headings of the columns of course are different for each sheet and are written in. Each page in the printed table contains 30 columns, and one advantage of this method of construction is that the original sheets, when completed, are sent to the printer as they stand, so that there is no copying required.

The actual size of the form employed is 31·69 inches in length and 16·20 inches in width, exclusive of the argument numbers at the left. A somewhat smaller form would have sufficed, but this gives ample space in each square for four figures, and was not found to be inconveniently large in use. The squares in the sieves were cut out by a punch made for the purpose. The sieves drawn in the plate have been reduced to suit the size of the page of this volume.

The sieves were formed thus: Take for example 13; the first uneven

multiple of 13 exceeding 3,000,000 is 3,000,023: add 26 continually till $3,000,000 + 13 \times 300$ is reached, and then throw out the multiples of 3 and 5; there are thus left 80 numbers, which correspond to the squares to be cut out from the sieve. The accuracy of the 80 numbers that remain was verified by differencing them; as the differences recur with a period of eight.*

In general the sieve for the prime p contains p columns, and it is to be noted that every sieve, whatever its length, has exactly 80 squares cut out, one in each line. To show that there must be one square cut out in each line it is only necessary to observe that p must have some multiple, not divisible by 2, 3, or 5, of the form $300\,q + a$, where a is any one of the 80 numbers less than 300 and prime to it. For, by a known theorem, if p be prime to r, and if $p, 2p, 3p, \ldots (r-1)\,p$ be divided by r, the remainders are the $r-1$, numbers $1, 2, 3, .\ r-1$; in this case, therefore, if $p, 2p, 3p, \ldots 299p$ be divided by 300, the remainders are the 299 numbers 1, 2, 3,... 299, and if $2p, 3p, 4p, \ldots$ and all the multiples of p divisible by 2, 3, or 5 be thrown out, the remainders divisible by 2, 3, or 5 are thrown out also, and the remainders left are the 80 numbers less than 300 and prime to it. Also, there cannot be two squares in the same line cut out from the sieve, for a being a given number, if $300q+a$ be divisible by p, the next number in the same line divisible by p is $300qp+a$, viz., is a number p columns further on.

The cube root of 4,000,000 is 158·74 .., and in a factor table extending to 4,000,000, the prime 157 appears once, and only once, as the least factor of a three-factor number, viz., for 3,869,893. Thus 163 and larger primes will only occur as least factors of two-factor numbers, and we may find the numbers to which they belong without the use of the sieves as follows:—

Supposing that we are constructing a factor table from the commencement, the least factor 163 first appears at the number 163×163, then at 167×163, 173×163, 179×163, 181×163, &c.; 163, 167, 173, 179, 181, &c., being the series of primes starting from 163; for we only consider products of two primes, of which 163 is the smaller, that is, numbers formed by multiplying 163 by the primes greater than itself. To obtain the results of the multiplications it is only necessary to add to 163×163 the product 4×163, and to this 6×163, &c.; the work standing thus—

$$\begin{array}{r@{\;=\;}l}
26{,}569 & 163 \times 163 \\
652 & 4 \times 163 \\
\hline
27{,}221 & 167 \times 163 \\
978 & 6 \times 163 \\
\hline
28{,}199 & 173 \times 163 \\
978 & 6 \times 163 \\
\hline
29{,}177 & 179 \times 163 \\
326 & 2 \times 163 \\
\hline
29{,}503 & 181 \times 163 \\
\text{\&c.} & \text{\&c.}
\end{array}$$

* It is easily seen that this must be so; for form the multiples of the prime p that are not divisible by 2, 3, or 5; these are $p, 7p, 11p, 13p, 17p, 19p, 23p, 29p$, then the next eight are obtained by adding $30p$ to each of these and so on. Thus the differences are $6p, 4p, 2p, 4p, 2p, 4p, 6p, 2p$, recurring with a period of eight.

This process will give all the numbers to which 163 belongs as least factor up to $(163)^3 = 4{,}330{,}747$, where the three-factor numbers commence. All that is required in order to reduce this to mere addition is a list of differences of consecutive primes from 163 to $\frac{1}{163}l$, l being the limit of the table, supposed less than 4,330,747, and a small table of even multiples of 163 from 2×163 to $2m \times 163$, $2m$ being the greatest difference between two consecutive primes between these limits. If l be 4,000,000, the nearest prime below $\frac{1}{163}l$ is 24,533; and the greatest difference is 52, between 19,609 and 19,661.* The accuracy of the work can be verified at any stage and as often as thought necessary by multiplying together the two factors. Of course in the calculation of the fourth million the commencement would be made at $18{,}413 \times 163 = 3{,}001{,}319$, the smallest number exceeding 3,000,000 to which the least factor 163 belongs.

There are thus two distinct methods, each of which has its special advantages, viz., the sieve method and the method by calculation of multiples. The latter is unsuitable for small primes, which appear as least factors of numbers having three or more prime factors; in fact, this method is only appropriate for two-factor numbers. On the other hand, the sieve method is rather more suitable for the entry of small primes, as, when the prime is large, the great size of the sieve is inconvenient; this method, however, points out *all* multiples of the prime, not divisible by 2, 3, or 5, whether they be two-factor, three-factor, four-factor, &c., numbers.

It is clear that up to 163 the sieve method should be used; and that for 163 and beyond we may employ the multiple method. Burckhardt states that he used sieves for primes up to 500, and the multiple method for higher primes. In the calculation of the fourth million sieves were used for primes up to and including 307, and the multiple method was employed for primes from 211 to 1999. The numbers corresponding to the least factors from 211 to 307 inclusive were obtained by both methods.

As the multiple method only gives numbers where the least factor is the given prime p, it follows that every number so found must correspond to an empty square, and the verification thus afforded of the entries already made was very valuable.

The sieve for 307 contains 307 columns, and therefore occupies four sheets all but one column: considered as a whole, therefore, it has only to be moved 11 times for the million, while the sieve for 13 has to be moved 257 times.†

Before the calculation was begun, it seemed as if the excessive length

* The greatest difference between two consecutive primes up to 100,000 is 72 (31,397—31,469). For a list of the differences that exceed 50 and other allied tables, see 'Messenger of Mathematics,' vol. vii. pp. 174–175 (March, 1878).

† In the fourth million the 13's were entered by a sieve consisting of 13 columns, the 17's by a sieve of 17 columns, and so on. In the fifth and sixth millions now in progress, the 13's were entered by a sieve of 78 columns, equivalent to six 13-sieves fixed together. This was found to greatly facilitate the entries, as the number of removals of the sieve was reduced in the proportion of 6 to 1, and there was less risk of error. The saving of time effected by the use of the 78-column sieve amounted to nearly one-half. For the 17's a sieve of 5×17, = 85, columns was used, for the 19's a sieve of 4×19, = 76, columns, and so on, the number of columns being made as nearly as possible equal to the number of columns (77) on a sheet. It was found also that by the use of the long sieves the sheets were much better preserved from wear and tear, as the sheet upon which the factors were being entered was in general almost wholly covered by the sieve, and so protected from friction, &c.

of the sieves (the 307-sieve is 10 feet 6 inches in length, and the 499-sieve 17 feet 1 inch) is productive of great inconvenience, and would also necessitate very great accuracy and care in the lithographing and printing of the sheets, so that the squares should correspond exactly, over so great a distance; and it seemed surprising that Burckhardt should have continued the sieve method so far. But this was on the supposition that the portions of the sieve would be all fixed together, so that it would consist of one long sheet. Experience, however, soon showed that nothing was gained by fixing the sheets together, and in fact that it was a positive inconvenience to do so. The sheets forming the sieve were numbered 1, 2, 3, &c., and all that was requisite was to use sheet 1 first, then sheet 2, then sheet 3, then sheet 1 again (if the sieve consisted of only 3 sheets), and so on; in fact, the long sieves were found to be quite as easy to use as the smaller ones. Above 307, however, it seemed to be scarcely worth while to construct the sieves, as so little use was made of them, and as the multiple method was preferable in consequence of the verification afforded by it.

The mode of work was as follows: The entries were made by the sieves, and one multiple of p obtained from each position of the p-sieve was divided out by p, in order to verify that the sieve was always rightly placed; this verification was employed for each position of every sieve. The numbers were then examined by Mr. Glaisher himself by the sieves. They were then examined a third time by the sieves, and every number ticked. The least factors obtained by the multiple method were read out and entered on the sheets; and they were subsequently read out again in a different manner and ticked. Any numbers found unticked were afterwards specially examined. The proofs of the table when printed will be read with the original calculations of numbers by the multiple method.

On the whole the method of construction is a very perfect one. It has been explained in some detail, because Burckhardt contents himself with a very brief sketch occupying only two paragraphs; and the process is sufficiently interesting to deserve a more complete account. Each sieve, as stated, has 80 squares cut out, one in each line; though of course, as there are only 80 squares cut out, whatever be the length of the sieve, many of the columns on the longer sieves are left intact. The patterns formed by the holes in the sieves were very curious, some being very regular, while in others the holes were very scattered, and no two were much alike. The sieves for 149 and 151 were remarkable, the holes running steadily up in the one case and steadily down in the other.* The reason for this is that these numbers are nearly equal to the half of 300, the difference between two adjacent squares in the same line, so that numbers distant from one another by even multiples of 150 are in the same line. For a similar reason the holes in the sieves for 59 and 61, and 29 and 31, show a steady ascent and descent. When the sieve for 23 is laid in its proper position on any one of the sheets a slightly ascending row of 13's (including some 7's and 11's) is seen through the holes; this is connected with the fact that $13 \times 23 = 299$, and differs from 300 by 1 only. Similarly, when the 43-sieve is laid on the sheets a slightly descending row of 7's is seen, as $7 \times 43 = 301$, and other instances of the same kind were remarked. It may be observed that when the pattern

* Several of the sieves, including those for 149 and 151, were exhibited to the Section at the Meeting at Dublin.

was regular (as in the case of the 13-sieve and 17-sieve, where the holes slope down in parallel lines) the entry of the factors was much facilitated. Great care was always required in order to be certain that no factor had escaped entry; but this examination was much more rapidly performed when the pattern was fairly regular. The size of the volume would, however, be increased very greatly if all the factors were given, without any proportionate advantage. Burckhardt's arrangement of the table is an admirable piece of condensation, as the least factors of 9,000 numbers are given, in the space of half a square foot, on each page.

It will be evident from this description that it would be just as easy to enter all prime factors in the table as to enter only the least; and if all the prime factors were entered the verification would be easier, and in the numbers entered by the multiple method no error could occur, unless the same mistake were made independently in entering both factors.

The methods described in this section are no doubt practically identical with those employed by Burckhardt, and the calculation of the million suggested no improvements upon them, except in a few matters of detail. The construction of the table, though very simple in theory, required such continual care at every step, and such constant supervision, that it could not be undertaken by any one who was not prepared to devote a great portion of his time to the work.

Eleventh Report of the Committee, consisting of Professor EVERETT, Professor Sir WILLIAM THOMSON, Professor J. CLERK MAXWELL, Mr. G. J. SYMONS, Professor RAMSAY, Professor GEIKIE, Mr. J. GLAISHER, Mr. PENGELLY, Professor EDWARD HULL, Professor ANSTED, Dr. CLEMENT LE NEVE FOSTER, Professor A. S. HERSCHEL, Mr. G. A. LEBOUR, Mr. A. B. WYNNE, Mr. GALLOWAY, and Mr. JOSEPH DICKINSON, *appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water. Drawn up by* Professor EVERETT (*Secretary*).

DR. STAPFF has continued his observations of the temperature in the St. Gothard Tunnel, and has contributed to the Swiss Natural History Society a paper* of 56 quarto pages, embodying the results.

The following is his description (pp. 26, 27) of the mode of observing the temperature of the rocks in the tunnel:—

"The exact determination of the temperature of the rocks in the tunnel formerly occasioned a notable expenditure of time and money. At first thermometers about a metre long (made by J. Goldschmid, of Zurich) were employed for this purpose; their tubes being cemented into a wooden cylinder, so that only the bulb (surrounded by a perforated steel cap) projected below, and the scale (extending from 15° to 30° C.) above. Tallow was poured round the wooden cylinder, and the whole thermometer was then thrust into a bore-hole a metre deep, so that only the

* 'Studien über die Wärmevertheilung im Gotthard,' i. Theil. 'Der Schweizerischen Naturforschenden Gesellschaft zu ihrer sechzigsten Jahresversammlung in Bex gewidmet,' von F. M. Stapff. Bern, 1877.

scale projected, from which readings were taken from time to time until the temperature became constant. The final reading had to be corrected not only for rise of zero but also for the temperature of the quicksilver in the thermometer tube which extends from the opening to the bottom of the bore-hole. Another very notable correction was required for the more or less oblique position of the thermometer; for the hydrostatic pressure of the quicksilver presses out the glass bulb so far that without change of temperature the long thermometer reads from 0°·4 to 1°·0 less in the vertical than in the horizontal position.

"After about from three to ten days, the reading of a thermometer luted into a bore-hole ceased to alter.

"Separate trials with thermometers of similar construction, but different length, showed moreover that, after months, the temperature of the rock at about a metre deep was still unchanged. This is obviously owing to the small difference of temperature between the rock and the surrounding air.

"From the observations at No. 8 and No. 15, in Table III., it is seen that the temperature at the bottom of the bore-hole was sometimes a little lower and sometimes a little higher than nearer its mouth.

"This mode of observing gave correct results, but was laborious and costly, not only on account of the necessity of making special bore-holes for the purpose, but because almost every experiment cost a thermometer. The projecting end was often maliciously broken off, and on account of the swelling of the wooden case it almost never happened that at the end of an experiment a thermometer was drawn out again uninjured.

"Hermann and Pfister remedied this latter evil by surrounding the thermometer tube, from the bulb to the scale, with a glass case, and this with a steel jacket. This arrangement, however, involves not only conduction through the steel, but also continual interchange of heat by currents of air in the glass case, from the mouth to the bottom of the hole. For these reasons the observations made with these thermometers could not be employed without intricate corrections.

"Later I tried a Thomson's maximum thermometer,* kindly placed at my disposal by Professor Everett, which (after previous strong cooling) was left for several days at the bottom of the bore-hole, closed air-tight. The results agreed with those obtained by other methods; but who can guarantee that the higher temperature prevailing in a newly-bored hole is always just so much depressed by the cold mass of the thermometer and its copper case, that the rock temperature alone determines the final indication of the maximum thermometer.

"This consideration induced me to employ for rock-temperature observations (and they also serve for air and water observations) the above-mentioned short thermometers with insulated bulbs, the first of which Professor Everett caused to be made by Negretti and Zambra for this express purpose. These thermometers, enclosed in a metal box provided with a handle, are thrust to the bottom of the bore-hole, which is at least a metre deep. To the handle is fastened a strong cord reaching to the mouth of the hole, by which it can be drawn out again at the end of the trial. The bore-hole, from the thermometer to the mouth, is stopped with greased rag or other similar material, as air-tight as possible. After two or three days, the thermometers have

* It was one of the protected Negretti maximum thermometers constructed for the Committee.

usually assumed the temperature of the surrounding rock, that is to say, their reading has ceased to alter. The insulation of the quicksilver prevents alterations during the drawing out and reading of the thermometer. The correctness of the result is in no way prejudiced by sediment from the boring which may yet remain in the hole. The pouring in of some water may even be useful in accelerating the experiment. Wet bore-holes with standing water are, however, to be avoided, because rock-temperature and water-temperature are not identical.

"In the manner last described, at every available opportunity, that is to say, when the work of the tunnel is from any cause compelled to cease for a few days, rock-temperature observations are now instituted in bore-holes ready to our hand. The observations are simple, give exact results if taken with proper precaution and sufficient duration of the experiment, and cause no further expense, since the thermometers, being sunk in the rock, are secured against wanton injury, and there are always bore-holes available."

Dr. Stapff further states by letter that, the two original thermometers supplied by Negretti and Zambra having been broken, he has had others made, in which he has introduced the improvement of hermetically sealing the outer glass case, instead of closing it with a waxed cork, which gradually admitted moisture.

In the Report for 1876 an account was given of the observations of Herr Dunker in a bore about 4000 feet deep at Sperenberg, and allusion was made to the undue weight which had been attached by some writers to the empirical formula in which Herr Dunker sums up his observations; a formula which indicates a retarded rate of increase, and, if extended to greater depths, leads to the conclusion that the temperature reaches its maximum at the depth of about a mile.

A discussion has been carried on in Germany on this subject,* chiefly in the 'Neues Jahrbuch für Mineralogie,' &c., and the best authorities seem to be unanimous in rejecting the hypothesis of a retarded rate of increase in the earth's surface as unwarranted, either by the Sperenberg observations or any others. Herr Dunker himself concurs in this opinion. Dr. Stapff also, though some of his own empirical formulæ indicate a retarded rate of increase, writes to Professor Everett in the following terms:—"As to my formulas, I beg you to remember that they are not constructed for expressing laws of Nature. They simply are made for facilitating the view over a heap of figures and data of observation. And generally I beg you to be sure that those formulas in my mind cannot express any law for the increase of warmth at greater depths than those in which the tunnel observations were made. The formulas give good means for eliminating empirically some of the influences of the shape of surface which occur in the profile of the mountain."

Mr. W. Galloway, one of H. M. Inspectors of Mines, has taken observations in Fowler's Colliery, Pontypridd, South Wales. The shaft is 846 feet deep, and the air current down it amounts to between twenty and thirty thousand cubic feet per minute.

In order to determine the normal temperature of the coal, a hole $1\frac{1}{2}$ inch in diameter was bored in the side of a narrow place that was being

* See papers by Mohr, Heinrich (two papers), Dunker, and Hottenroth, in the 'Neues Jahrbuch' for 1878, 1876, and 1877, by Brauns, in the 'Zeitschrift für die gesammten Naturwissenschaften,' 1874, p. 483, and by Hann in the 'Zeitschrift der österreichischen Gesellschaft für Meteorologie,' 1878, p. 17.

rapidly driven in the solid coal. The hole was bored in the very face, to the depth of four feet. The thermometer (one of the Committee's slow-action non-registering instruments) was placed at the inner end; then a wooden cylinder of nearly the same diameter as the bore-hole, and 9 inches long, was pushed in until it came in contact with the copper case of the thermometer; and lastly a wooden plug, wrapped round with cloth, was driven firmly into the mouth of the hole. The thermometer was at 58° F. when it was put into the hole, and after remaining there from 2 p.m. on August 25th, 1876, to 3.45 p.m. on the following day, it stood at 62°·7. There was no water whatever in the hole, and the depth below the surface of the ground was 855 feet.

The circumstances of this observation seem to preclude any considerable disturbance of the normal temperature; and combining it with the mean annual temperature at the surface, which is said to be 51°·5, we have an increase of 11°·2 F. in 855 feet; which is at the rate of 1° F. for 76 feet.

Two other observations were taken in other parts of the mine. They are not directly available for the purposes of the Committee, but were intended to test the influence of air-currents on the temperature of the coal; and they show variations of 2° or 3° according to the season of the year.

Observations are being taken for the Committee by Mr. G. F. Deacon, Borough Engineer of Liverpool, in a bore which has attained the depth of 1004 feet, in connexion with the Liverpool Waterworks at Bootle.

The temperature at this depth is 58°·1. The observation nearest the surface was at the depth of 226 feet, the temperature at this depth being 52°. We have here a difference of 6°·1 in 778 feet, which is at the rate of 1° for 128 feet, and the same rate is approximately maintained throughout the descent. For instance, at 750 feet the temperature was 56°, which gives 1° for 131 feet by comparison with the depth of 226 feet, and 1° for 121 feet by comparison with the bottom.

The bore is 24 inches in diameter, and the observations were taken with a protected Phillips's maximum thermometer every Monday morning. The operation of boring was continued up to twelve o'clock on Saturday night, and was not resumed till the temperature had been taken on the following Monday. The time that the thermometer remained at the bottom was not less than a quarter of an hour, and was sometimes half an hour.

The rock-formation consists of the pebble beds of the Bunter or lower trias, and most of it is described as hard, close-grained, and compact. The speed of boring is indicated by the dates of the observations at 226 and 1004 feet, the former being Nov. 12th, 1877, and the latter Aug. 12th, 1878. A month was lost by the jamming of the drilling tool, in May and June, 1878, when a depth of about 890 feet had been attained.

The depth from the surface of the ground to the surface of water in the bore has gradually decreased from 66.feet, when the bore was at 318 feet, to 52 feet when the bore was at 800 feet, and to 51·1 feet at the present depth. It would thus appear that the inflow of water from below has increased with the depth attained. There is a slow percolation from the upper part of the water-column to an underground reservoir near at hand, the top of the water-column being considerably higher than the top of the water in the reservoir. Mr. Deacon remarks that the

slow upward flow which supplies the water for this gradual discharge is favourable to the accuracy of the observations (which have always been taken at the bottom,) by checking the tendency of the colder and heavier upper water to descend and mix with the lower. As bearing on the subject of the disturbance of temperature by the stirring of the water in boring, as well as by the generation of heat in the concussions of the tool, it may be mentioned that the last observation before the month's interruption by the jamming of the tool was 57° 5, at 886 feet, and the first observation after the extraction of the tool was 57°·0, at 898·6 feet; the former being on May 20th, and the latter on July 1st. The smallness of the difference between these two temperatures seems to indicate smallness of disturbance by the action of the tool.

It appears from these various circumstances that the observations are entitled to considerable weight, and that the rate of increase of temperature downwards at Liverpool is exceptionally slow. It will be remembered that the rate found by Mr. Fairbairn, at Dukinfield Colliery, in the adjacent county (Cheshire), was also very slow, though not nearly so slow as that indicated by these Liverpool observations.—(See our Report in the Volume for 1870.)

Mr. E. Wethered, of Weston, near Bath, has also commenced observations in a colliery in that neighbourhood. Mr. J. Merivale, of Nedderton, near Morpeth, has received a thermometer for observations in a colliery. Mr. J. T. Boot, of Hucknall, near Mansfield, has received a second thermometer (in place of a broken one) for observations in a deep bore, and Mr. Rowland Gascoigne, of the same town, has received one for a similar purpose.

In the eleven years which have elapsed since the appointment of this Committee, a large amount of useful work has been done, by methods of observation not requiring any elaborate or expensive appliances, or any special training on the part of the observers.

Two difficulties are encountered in investigating underground temperature. We have to contrive instruments which shall truly indicate the temperature at the point of observation, and we have further to ensure that this temperature shall be the same at the time of observation as it was before the locality was artificially disturbed.

As regards the first of these difficulties, the Committee have been completely successful, and have largely increased the resources at the command of observers.

But in regard to the second difficulty, the same amount of success has not been attained. The circulation of water in bore-holes and of air in mines are disturbing elements difficult to deal with. Even such firm plugging as was employed to isolate portions of the water-column in the great bore at Sperenberg cannot altogether remove the error arising from convective disturbance; for the long-continued presence of water at a temperature different from that proper to the depth affects the temperature of the surrounding rocks, and the temporary isolation of a short column would not abolish this source of error, even if the plugs themselves were impervious to conduction and convection.

After the experience which has now been gained of rough and ready methods, it is time to consider the propriety of resorting to a more special method, which has been more than once suggested, but has hitherto been postponed on account of the additional labour and skill which would be requisite for carrying it out.

There can be no doubt that the surest way to bring any point of a boring to its original temperature is to fill up the bore, and reduce it as nearly as possible to its original condition. Several instruments have been contrived which, when buried in the earth, with wires coming from them to the surface, admit of having their temperature observed by electrical means.

One of these is Siemens' resistance thermometer, another is Wheatstone's telegraphic thermometer, of which a description will be found in the Report of the Dundee Meeting of the British Association; another is Becquerel's thermo-electric apparatus, which has been employed by its inventor and his son and grandson for some forty years. It is described in the following terms in the first report of this Committee (1868):—

"The thermo-electric method might also be followed with great advantage. Two wires, one of iron and the other of copper, insulated by gutta-percha or some other covering, as in submarine cables, and connected at their ends, might be let down, so as to bring their lower junction to the point where the temperature is to be taken, their upper junction being immersed in a basin of water, and the circuit completed through a galvanometer. The temperature of the water in the basin might then be altered till the galvanometer gave zero indication."

Sir Wm. Thomson now adds the recommendation, that, in carrying out this method, the two wires, each well covered with gutta-percha, should be twisted together; that the wires should be stout and as homogeneous as possible throughout, and that a piece of stout copper tube should be attached to the lower junction, this tube being uncovered and in close contact with the earth all round, its purpose being to ensure that the junction takes the proper temperature.

It would probably be desirable, in filling up the bore, to mix clay with the original material, to render it watertight, for it would be impossible to render the filling of the bore as compact as the surrounding rock.

Several pairs of wires would be buried in the same bore, with their lower junctions at different carefully measured depths.

The upper junctions would be kept in a room provided with a steady table for a mirror-galvanometer.

Report of the Committee, consisting of the Rev. Dr. HAUGHTON, Prof. LEITH ADAMS, Prof. BARRETT, Mr. HARDMAN, *and* Dr. MACALISTER, *appointed for the purpose of Exploring the Fermanagh Caves. Drawn up by* Mr. THOMAS PLUNKETT, *Enniskillen, for* Dr. MACALISTER, *Secretary of the Committee.*

PROBABLY there is no locality in Ireland where there are so many interesting caves found as in the region of Knockmore, in Fermanagh. Fifteen of these caves have been explored during the past three years, every one of which yielded memorials of man, and were no doubt used by savage tribes as dwelling-places.

A.—The first cave explored this year was partially excavated last year. It penetrates a deep escarpment on the eastern side of a rocky hill, and

attains a length of about fifty yards, and in width varies from three to nine feet The floor was irregularly formed, some parts of it being quite level, but in some places the floor passed in with a very swift incline.

The first or top layer was composed of dark mould, and varied in thickness from one to two feet deep. In this layer bones of the sheep, goat, and *Bos longifrons* were found, also some sea shells and a large iron cloak-pin or skewer, 5½ inches long, which had a ring on the head or larger end of the pin Underneath this stratum there was a deposit of rock *débris* and yellow clay, in which were found large angular blocks of limestone which had fallen from the roof. This stratum was very irregular in depth, and varied from two to eight feet deep; charcoal, rude pottery, and a very large quantity of animal bones—some of them broken—were dug out of this stratum, also flint flakes and one bone pin. Underneath the above deposit there was a layer of calcareous breccia, covered over in some places with sheets of stalagmite;.the latter in some places attained a thickness of two feet. Animal bones were found embedded in the stalagmite, also charcoal, and in the stratum underneath, on which the sheets of stalagmite rested, bone pins and flint flakes were found associated with broken bones.*

The next stratum reached during the excavation was composed of brown tenacious clay, which resembled brick earth and rested on gravel, and was no doubt deposited at the period when water traversed the cave. This was excavated to a depth of ten feet, but no animal remains or work of art was found in it.

B.—"The Ram's Cave" was the second explored, and occurs in the top of a cliff several hundred feet high. It is a small chamber, about four feet high and ten feet long, and was very dry inside. The deposit on the surface of the floor was composed of black mould, which had a depth of two feet, and contained charcoal, burnt bones, and a bronze pin. The next stratum was composed of a gravelly kind of earth, and contained a few angular blocks of limestone. This stratum yielded rude pottery, charcoal, and the bones of the red deer, wild boar, goat, sheep, and fox.

C.—The third cave examined was about six feet wide, and extended into the rock for a distance of twelve feet. This cave yielded a large quantity of broken pottery, some of it very rude. The first stratum removed was composed of carbonate of lime mingled with brown earth, and contained bones of the pig and red deer, and pieces of pottery which bore traces of ornamentation. The next layer removed was of an average thickness of about eighteen inches, and was composed of dark mould, and contained a quantity of charcoal and rude pottery devoid of any ornamentation, also broken bones belonging to *Bos longifrons*, horse, deer, dog, and sheep.

D.—The fourth cave explored opens out on a rocky slope, and the surface of the floor passes in with a gentle incline for a distance of thirty yards, when the passage becomes entirely choked up with a deposit of stalagmite. The surface of the floor was covered over from end to end with rough angular limestones; while these stones were being removed, bones of the horse and boar were found mingled with them. These stones rested on a deposit of yellow clay and carbonate of lime. During the removal of this stratum a quantity of animal bones were found associated

* The bones have been submitted to Dr. Macalister for examination, and his report will be presented to the next meeting of the Association. The caves have no local names, so we have indicated them by letters.

with charcoal; nothing else of any interest was found during the exploration except the tusk of a boar, which was whetted to a sharp edge, and probably was used as a knife by the cave-dwellers.

E.—"Shining Rock" cave enters a rock on the south side of Knockmore, and prior to its excavation was nearly filled to the roof with rubbish and *débris*. The top stratum was almost entirely composed of vegetable earth, and of an average depth of two feet, and yielded some bones of fox, dog, and deer. The layer underlying this contained a quantity of bronze or iron clay, also bones of the pig, deer, and rabbit. Near the bottom of the cave a quantity of bones were found in calcareous breccia. A large portion of the bones found in the lower strata of this cave were bound up in this material.

F. is a commodious cave a short distance from the above; it passes through a rocky hillock and can be entered at either end. Midway it assumes the form of a square chamber, which measured ten feet high and six feet broad; the top stratum was of a dark mouldy character, and yielded similar bones as the other caves explored. In the lower stratum, which was composed of reddish clay, flint flakes and marine shells were found.

The explorations were suspended after the exploration of F cave, as the probability is that none of the caves in this district will yield bones of extinct mammalia or objects of any great interest.

Sixth Report of the Committee, consisting of Professor PRESTWICH, Professor HARKNESS, Professor HUGHES, Professor W. BOYD DAWKINS, Rev. H. W. CROSSKEY, Professor L. C. MIALL, Messrs. G. H. MORTON, D. MACKINTOSH, R. H. TIDDEMAN, J. E. LEE, JAMES PLANT, *and* W. PENGELLY, Dr. DEANE, Mr. C. J. WOODWARD, *and* Mr. MOLYNEUX, *appointed for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation. Drawn up by the* Rev. H. W. CROSSKEY, *Secretary.*

THIS Committee has pursued its inquiries, and is able to record many new and important observations. In many districts, however, the observations are not yet completed, and it will be necessary for the work of the Committee to be continued for some time, before they can be justified in classifying the facts collected, or in presenting any theoretical conclusions.

The Committee are favoured with the following notes on *Boulders near Kendal* by Mr. J. R. DAKYNS:—

The most remarkable boulders near Kendal are those of the granite of Wastdale Crag, near Shap Wells. These boulders are specially interesting, for two reasons: in the first place, boulders of the granite of Wastdale Crag, or the Shap Granite, as it is often called, can be readily identified

by means of the large crystals of pink orthoclase felspar which the rock contains; and, secondly, the distribution of these boulders near Kendal would seem to show that they must have travelled over the high ground south of the granite area, and not followed the course of the present drainage; for I have traced these boulders, north of Kendal, directly towards this area on the one hand, while on the other hand I have not noticed them in the depression extending from Kendal to the river Lune, along which the London and North-Western Railway runs, east of Docker Garth; but as I have not minutely examined this part of the country, I cannot say which is the precise eastern limit of the boulders. It seems, then, that the Shap granite boulders came nearly due south from Shap Fells, across the high ground over which the old coach road goes from Kendal to Shap. The highest point where the granite occurs in place, viz., Sleddale Pike, 1659 feet above the sea, is higher than the greater part of this ground; but the greater part of the granite area is lower than the ground across which the boulders travelled in their southerly course; nor is there immediately to the north of the granite any ground as high as the granitic fell itself. The greater part of this fell, sloping northward, drains into Wet Sleddale, whose waters, forming the river Lowther, flow north, and, joining the Eden, go out to sea by the Solway; the remaining small portion, including the site of the quarries, facing southward, overlooks Wastdale Beck. This beck flows N.E. along the strike of the rocks to Shap Wells, where its waters turn sharp at more than a right angle, and thence flow S.S.E., and join the Lune at Tebay. On the south side of Wastdale rise the Upper Silurian falls to the heights of 1691, 1589, 1494, 1588, 1544, 1523 feet above the sea; the lowest part of the range being the Hause, over which the coach road goes. The height of this point is not given on the Ordnance one-inch map; but it is between 1300 and 1500 feet above the sea, and is probably over 1400. Across this high ground the Shap granite boulders travelled south from their parent rock, which attains an extreme height of 1659 feet at its most westerly outcrop, and a height of 1478 on its steep southward face; while north of these points the granitic area falls gently away northward, the centre of the area being about 1373 feet above the sea.

The general due south course of the boulders is further shown by an examination of their distribution south of Kendal. It is not to be expected that very many boulders should now remain scattered over the surface of the rich and highly cultivated land near Kendal; they have mostly been long since cleared off the surface of the pasture and meadow land, and are now to be found built into the walls, where, however, they are good evidence of their existence in the country, because boulders are not carted a long distance for walling in a country that has plenty of such material at hand; but there are some large boulders still remaining unmoved, from the place where they were once dropped by the ice, and in ploughed lands others are from time to time turned up and placed among heaps of stones for road metal.

I have traced these boulders as far south as Milnthrop; they occupy a narrow band of country, whose long axis points directly for the granite of Shap Fells. I have not seen any west of the river Kent. The most westerly I have seen are some near Hincaster, still lying undisturbed in a lane. A line drawn from Sleddale Pike, the most westerly outcrop of granite on Shap Fells, to these boulders bears south by west. The most easterly that I have noted in this neighbourhood is a large one in a field

near Windy Hill, about two miles S.E. of Kendal railway station; but I once saw one high up on the side of Grayrigg Fell, north of Grayrigg Tarn, which lies a good deal farther east.

The chief boulders still in their original position are the following: Several on Spital Wood; one near the Kendal reservoir; one or two on the Castle Hill, Kendal; the one near Windy Hill; one on the east side of Helm; some boulders of granite and of the altered rock surrounding the granitic area near the footpath by Murley Moss to Oxenholme; one in a drift bank cut through by the canal near Larkrigg; several in the fields east of Stainton; others near the footpath from Stainton to Sedgwick; one on the top of a drift hill, half a mile due west of Sellet Hall; several near Hincaster; some in front of a farm house at Wath Sutton. I have also found granite boulders on the roadside between Natland and Helm, at the inns near Helm End, and in a field a quarter of a mile west of Storth End, and on the road half-a-mile N.E. by north of Storth End, and at the bend of road east of Milnthrop station, besides in many other places, which it would be tedious to mention.

Boulders of the dark compact altered rock that surrounds the granitic area are generally found along with the granite boulders.

When the localities where granite boulders occur are marked on a map, the steady lineal north and south direction of their course is very striking.

Boulders of the ordinary volcanic rocks of the Lake Mountains indicate other directions for the ice-flow; thus a large boulder of volcanic breccia from the Lake Mountains may be seen lying on the side of the Sedbergh road, about two and a half miles out of Kendal, and east of the line of granite boulders. As the granitic area of Shap Fells is at the extreme east end of the volcanic rocks, this boulder must have crossed the line of flow along which the granite boulders travelled. Amongst noteworthy boulders is a monster boulder, by the natives designated by the undignified term of a "cobble," of volcanic ash in the beck course at Stainton, measuring $9 \times 6 \times 4$ feet, or 216 cubic feet.

The distribution of boulders on the bare limestone fells in the neighbourhood of Kendal is in some particulars remarkable. Thus, on Farleton Fell, a conspicuous hill of bare limestone on the east side of the Lancaster and Carlisle Railway, there are very many large limestone boulders lying on glaciated surfaces, and often having pebbles and small boulders of Upper Silurian rock beneath them. Some of these limestone boulders, too, are standing on edge with their planes of stratification vertical or highly inclined, so that there can be no doubt about their being *true boulders*. On the same fell there are, as already stated, many small boulders of Upper Silurian rock; but I have met with no boulders of volcanic rock or of granite on this fell. Unfortunately I could find no good scratches to show the direction of the ice-flow; but, considering the great size and number of the limestone boulders, and the smallness of the Upper Silurian ones, I should be inclined to think the ice came from the N.W., in which case it would traverse a great extent of limestone country, and the Upper Silurian rocks that were the origin of the boulders would be several miles distant; and this transport of boulders probably took place while the adjacent limestone area was free of drift, and therefore before the transport of the granite boulders, which, as being found in the drift that now covers the low ground N.W. of Farleton Fell, belong to the time of the deposition of this drift.

The limestone fell immediately west of Kendal, which ends in the fine escarpments known as Scout and Cunswick Scars, overlooking a broken foreground of Upper Silurian rocks to the Lake Mountains in the distance, is singularly free from limestone boulders. This is only what might be expected, as it is the extreme north end of the limestone area; for this fell is plentifully strewn with large boulders of Upper Silurian rock, and small ones of volcanic rocks, though there are a few large boulders of volcanic rock as well; for instance, one well-glaciated boulder of volcanic ash about a mile and a half S.W. of Kendal, and a large one above Cunswick Scar, near the footpath to Kendal.

Whitbarrow, too (another bare limestone fell), is generally free of limestone boulders, except at the south end, where there are several large ones; but Silurian boulders are pretty generally distributed over it, and amongst these one large boulder of ash deserves notice. This boulder, which is a tolerably conspicuous object on the fell, is situated on the western side of the fell, perhaps a mile or better S.W. of Row. It is about six feet high, and is split in two, the inner surface of one portion corresponding to that of the other. But the southern portion has been moved away from its fellow, slightly on the western side, but as much as several feet (five or six) on the east; the general result being motion from north to south. One might fancy that the boulder was originally split as it fell off the end of the ice, and that subsequently the ice had shoved one part slightly away from the other. Connected with boulders is the difficult subject of the accumulation of drift. For a geologist who has a day to spare at Kendal no more instructive walk can be recommended than this. Walk out along the Kendal and Sedbergh road for about five or six miles till you come to the summit level, 930 feet above sea, then turn south acoss the fell called New Hutton Common to its summit, 1097 feet high. Looking S.W. from this point you will see spread out before you in the Gatebeck and Saint Sunday Valleys, a tumultuous assemblage of mounds, a truly wonderful sight. These mounds are the vast moraine, or system of moraines, which the great glacier, or ice sheet if you will, of old threw down in the low ground between Helm on the right and the uplands on the left, ending in Scout Hill.

And if anyone wishes to see moraines of the ordinary Swiss type, shed by local glaciers, let him go to the recesses of the mountains to the head of Long Sleddale; there in one of the finest dales of the lake country, though one but rarely visited—he will see plenty such.

Mr. D. Mackintosh reports some new facts relative to the derivation of boulders already discovered by members of the Committee, the existence of several large boulders previously unrecorded, and the extent to which Ireland has sent erratics into England.

In our Report for 1875 there is a full account of many large blocks of felspathic rock in the neighbourhood of Bromsgrove, Worcestershire. I have principally examined them between Catshill and Hagley, in a district from which granite would appear to be entirely absent. From a comparison of their shape, size, appearance of weathered surface and internal structure as revealed by chips, I have no doubt whatever that these boulders are what may be called an *overshot load* from the great Arenig stream of erratics which has found its way through Llangollen Vale into the central plain of England, and which has left large blocks about Chirk and Welsh Frankton (west of Ellesmere). In our Report for 1876 there is an account of the Arenig dispersion, and the enormous Cefn felstone

boulder is mentioned. Some distance S.E. of Cefn, and about a quarter of a mile S.E. of Chirk Bridge, on the east side of the Holyhead road, there is a felstone boulder, the greater part of which is evidently buried. The exposed part is about 13 × 7 feet, and three feet above ground. Between this boulder and Welsh Frankton, Arenig erratics are numerous, and some of them are very large. A short distance west of Welsh Frankton, and close to where a canal is crossed by the main road, 8 × 8 feet of an Arenig boulder may be seen above ground. It is somewhat varied in structure, part of it approaching the character of hornstone. Around Welsh Frankton there are numerous moderate-sized, and a few very large Arenig boulders. One, close to Mr. Oswell's house, is quite 8 feet in average diameter; and another, a few yards distant, $8\frac{1}{2} \times 6 \times 5$ feet. They are accompanied by good-sized boulders of Silurian grit and Carboniferous sandstone and quartzite from the Welsh borders.

Mr. Mackintosh lately found a number of lumps of a very white rock in a gravel-pit which had been excavated in an undulating continuation of the large and abrupt mounds of middle drift age which may be seen south of Ellesmere, Shropshire. He has since found many more lumps at Wrexham, and, after much inquiry, he cannot hear of any rock like it *in situ*. It looks very much like silicified chalk, but the fossil evidence is in favour of its Jurassic age. A fragment of lias, with characteristic fossils (now in the possession of Mr. W. Shone), was very lately found about 8 feet down in upper boulder clay at Guilden Sutton, near Chester; and Mr. Watts, F G.S., has found large chalk flints and a specimen of *Gryphæa incurva* in a boulder clay at Piethorne, near Rochdale. These erratics, in all probability, came from Ireland.

Mr. MOLYNEUX reports as follows upon *Boulders in the Midland District*:—

Stretching westwards from the town of Burton-on-Trent, and bounded on the south and east by the Trent Valley and on the north by that of the Dove, is a range of table-land, from 100 to 300 feet above the levels of those rivers, and comprising within its limits the broad acreage anciently included in the Royal Forest of Needwood. The whole area is covered more or less thickly with one or the other or each of the three different deposits which constitute the Boulder clay group of the Midlands. These deposits consist in well-defined divisions of sand, gravel, clay, and boulders, and are of an aggregate thickness of 120 feet. On the less elevated face of the country under consideration they repose directly on Red marls, and on the higher tracts of Christchurch-on-Needwood and Bagot's Park are the lower division of the Rhætic beds, which there appear in characteristic force and condition. The boulders, or rock masses, occur principally at from three to ten feet below the surface, intermixed with blue and yellow clay, and consist of angular, sub-angular, and rounded fragments of Carboniferous limestone and chert, Yoredale sandstone, Millstone grits, Granites, Porphyry, Syenite, Greenstone, Trachyte, and Toadstone, with smaller fragments of Liassic and Oolitic rocks, many of which bear the usual evidences of the action of ice. There is also, stretching across the high grounds of Hanbury Woodend, running east and west, an extraordinary trail of Chalk flint flakes. The Boulder clays, with their associated deposits, cap the high land of Waterloo Hill and Moat Bank on the east side of the Trent Valley, and the same description of rock masses

enters largely into the composition of the basement bed of the valley gravels at Burton-on-Trent, but in a more rounded condition. Gryphæa and other Liassic shells are frequently found in the sand and gravel of each deposit.

During some drainage operations at Sinai Park, overlooking Burton-on-Trent, many hundreds of tons of boulders were excavated, the weight varying from a few pounds to half a ton each. I am in a position to place on record one only of these boulders, which deserves a place in the catalogue of Staffordshire erratic rocks. This was exhumed from near the surface of some gravel workings at Postern House, three miles due west from Burton-on-Trent, and where the letter P, of Postern House, in the Ordnance Survey map, occurs. It lay at 180 feet above the Trent Valley, and is an angular fragment of coarse Millstone grit five feet six inches long by four feet six inches deep, one of its sides being planed down by ice action. Another sub-angular boulder of Syenite was about two years ago obtained from the bottom of a well sunk in the valley gravel at the brewery of Messrs. Truman, Hanbury, and Buxton, at a point just north of the letter B in Burton-on-Trent, between the road and railway, as shown on the Ordnance map. It lay at twenty-four feet from the surface, embedded in a foot or two of Boulder clay, which there comes between the valley gravel and the Red marls, and which with other similar evidences is conclusive proof of the excavation of the Trent Valley hereabouts before the Boulder clay period. The boulder weighs nearly a ton, and was removed for preservation to the residence of the writer, about a mile south of Burton-on-Trent on the Lichfield road.

Mr. James Plant continues his reports upon the *Boulders in Leicestershire*:—

(1.) *Isolated Boulders.*

The "great erratic" from Humberston (briefly described in a former report) has been recently laid quite bare to the bottom.

There is a great quantity of traditional material connected with it, and it must have excited considerable interest in the "olden time." Several distinguished antiquarians have written upon it, and described these traditions.

I believe that this block has a certain relation to the monolith "St. John's Stone," exactly three miles S.W. by W. across the valley of the river. Both blocks are on the *rise* of the land, and visible from either locality if a fire was lighted on each at night.

A festival (Romish) was formerly held near the St. John's Stone (a vestige of old "fire, or sun worship") on Midsummer Day, and this Humberston block *would be in the line of the greatest eastern sunrise.*

This boulder is situated in St. Mary's parish, on the Pochin estate, on Kirby's Farm, Humberston, Leicestershire, close to the *bend* of the road from Humberston to Thurmaston. It measures 8 feet × 7 feet × 5 feet, and its weight is nearly 20 tons. It is pentagonal, *edges sharp and angular.* Longest axis is N.W. by S.E. It has about six deep *irregular* grooves two inches deep on the top, sides nearly vertical and smooth, and the striations are in direction of the longer axis. It is composed of the syenitic granite of Mount Sorrel, distant 5½ miles N.W. from the locality. Many legends are connected with this block, and it is known

in the locality as *Helstone*. It is 230 feet above sea (ordnance datum), and marks a boundary on the farm; all land on the farm east of the stone is called Ost-end, and all west West-end. It lies amongst lower glacial "*drift-clay*," and is quite isolated. It was thought by many persons to be the rock in *situ*. It rests upon *worn* surface of Rhætic beds. It is to be removed to the grounds of the Leicester Museum, and photograph taken before removal.

Another large isolated boulder is situated at Loseby, Leicestershire, on the estate of Sir F. T. Fowke, Bart., Loseby Hall, Leicestershire. It measures 5 feet 3 inches × 3 feet 5 inches × 2 feet 4 inches. It is rounded and worn, is long shaped, has never been moved by man, and has small groovings at various angles on all the sides exposed. It is composed of millstone grit, which occurs 35 to 40 miles N.W., but it may have travelled 80 miles if it came from the north. It is 650 feet (ordnance datum) above the sea; and rests in "upper glacial drift," composed of sand, flints, chalk, lias, sandstone, millstone grit and pebbles of various sorts, and lumps of clay.

(2.) *Groups of Boulders.*

The *first* group recently found in the "Coleman Road" (a new road about two miles from here) is quite a new district for boulders. The group occurs in Evington parish, near Leicester; the road is about two miles long, in a "cutting" through "Crown Hill." The largest boulders are 3 feet 3 inches × 3 feet × 2 feet 6 inches; the smallest 1 foot 3 inches × 1 foot × 1 foot. They are angular and sub-angular, except the block of "limestone," which seems rounded, but it may have been done in *situ*. All have been moved in excavating the road, and many broken up. Most of the sandstones, grits, and limestones, have striations in various directions on the top and sides, and at different angles. The localities at which rocks of the *same nature* as the boulders occur are—Mount Sorrel, Groby, and Markfield, east side of "Pennine Chain," in valley of River Derwent, and Stanton, valley of the Erewash, Sherwood Forest, country round Nottingham, Ticknall, Crick Hill, Wirksworth, Derbyshire. The distances of these localities are as follows:—

	Miles.
Mount Sorrel	8 N.N.W.
Groby	8 N.W.
Markfield	10 N.W.
Stanton	22 N.W.
Erewash	24 N.W.
Derwent	35 and 40 N.W.
Sherwood and Nottingham	24 N.N.W.
Ticknall	20 N.W.
Crick and Wirksworth	40 N.W.

Sixteen blocks were measured and examined; 7 of these were syenite and syenitic granite, 5 triassic sandstones, 2 millstone grit, and 2 mountain limestone. A great many of the limestones, grits, and sandstones have been broken up for road metal, being softer than the syenites. The group is about 350 feet above the sea. The area covered is about 50 yards long by 10 yards wide. A few boulders occur in other parts of the road, but of smaller dimensions; many boulders are left *in the sides of the cutting*, and every indication seems to be that great numbers spread out in the

hill. The boulders were found at depths of four, six, and eight feet in cutting the road through the hill, many lying in the gravel (flint gravel) on the *narrow* end, as if all the materials had been solidified when deposited on the lower lias clay.

A *second* group occurs in Aylestone parish, near Leicester, near the third milestone from Leicester. The largest boulder is 3 feet × 2 feet 10 inches × 2 feet 10 inches; and the smallest 2 feet × 1 foot × 10 inches. The boulders are angular, and all having been moved out of a sand-bed; no striations can be seen. They are derived from Groby, Markfield, and Charnwood Forest. Groby is six miles distant N.N.W., and Markfield eight miles N. All are composed of syenite. The group is 280 feet above the sea, and has *about two feet of gravel over it*, and covers an area about ten yards square. The boulders were all covered by a deposit of gravelly drift, and were found in the sand.

A *third* group occurs in Aylestone parish, Belmont Park, Leicester, half a mile east of Aylestone. The largest boulder is 2 feet 6 inches × 2 feet × 1 foot 10 inches; the smallest is 1 foot × 10 inches × 9 inches. The boulders are angular and sub-angular; and all have been moved in making new roads. There are no striations. Rocks of the same nature are found at Mount Sorrel, Groby, Markfield, Bradgate Park, in Charnwood Forest, at a distance of six to eight miles. They are composed of syenite greenstone, syenitic granite, 20 blocks were measured and examined. The group is 320 feet above the sea, and covers an area about 100 yards by 20 yards. It is covered by gravel containing flint.

A *fourth* group occurs in St. Margaret's parish, on the estate of the Freehold Land Society, Leicester, on the road leading to Evington from Leicester. The largest boulder is 3 feet 1 inch × 2 feet × 1 foot 10 inches, and the smallest 1 foot 5 inches × 1 foot 2 inches × 1 foot 1 inch. The boulders are rounded, angular, and subangular; out of twelve boulders eight are syenitic granite, two triassic sandstone, one millstone grit, one oolite. The group is 290 feet above the sea, and covers an area 100 yards square. It was uncovered by making foundations for houses; all have been moved. No striations exist on the *igneous* rocks, but the sandstones and oolitic blocks are striated at various angles. Igneous rocks of the same nature are found at Mount Sorrel, Groby, sandstones at Nottingham, oolitic rocks at Ketton near Stamford, at the respective distances of eight, twenty-six, and twenty miles.

A *fifth* group, occurs in Evington parish, "Spinney Hills" Road, Leicester The largest boulder is 3 feet × 1 foot × 1 foot; the smallest, 2 feet 6 inches × 1 foot 2 inches × 1 foot 4 inches The boulders are sharp, fresh looking, angles all round; no striations are visible Rocks of the same nature are found at Mount Sorrel, a distance of six and a half miles. They are composed of syenitic granite, and are at the height of 290 feet above the sea. They have been moved out of a field to the side of the road, but are on the S.E. side of "Spinney Hills," and therefore must have *come over them*.

A *sixth* group occurs in Saxe-Coburg Street, Leicester. The largest boulder is 3 feet 3 inches × 2 feet 2 inches × 2 feet; the smallest, 2 feet 6 inches × 2 feet × 1 foot 10 inches. The boulders are angular and sub-angular; no striations are visible. Rocks of the same nature occur at Mount Sorrel, a distance of six miles N.N.W. They are composed of syenitic granite, and are 260 feet above the sea, and cover an area twenty yards square. They have been exposed by the excavations for streets and sewers, and foundations of houses.

A *seventh* group occurs on the Town Estate, Victoria Road, Leicester. The largest boulder is 2 feet 9 inches × 2 feet × 1 foot 10 inches, and the smallest 1 foot 8 inches × 1 foot 6 inches × 1 foot. The boulders are angular, and without striations. Rocks of the same nature occur at Groby and Markfield, a distance of five miles and seven miles N.W. They are composed of syenite, and are 260 feet above the sea, covering an area of 30 yards × 10 yards. They have been exposed in excavations.

An *eighth* group occurs at Clarendon Park, near Leicester. The largest boulder is 2 feet 6 inches × 1 foot 5 inches × 1 foot 7 inches, and the smallest 1 foot 9 inches × 1 foot 5 inches × 10 inches. Three are rounded, others are angular and sub-angular, but the rounded edges may have been done in *situ*. All have been moved out of excavations; no striations. Rocks of the same nature occur at Mount Sorrel at a distance of seven-and-a-half miles N.N.W. The boulders are all composed of syenitic granite, and are 300 feet above the sea, covering an area of 20 yards × 10 yards.

Report on the Present State of our Knowledge of the Crustacea.— Part IV. *On Development. By* C. SPENCE BATE, *F.R.S.*

[PLATES V., VI., & VII.]

HAVING, during the last three Reports, given an account of the present state of our knowledge of the dermal skeleton of the higher forms of Crustacea as it appears in various genera in the adult animal, it is desirable that we should next obtain some knowledge of the forms that these animals undergo in their passage from the ovum to the adult.

It is highly probable, judging from the very perfect resemblance to the parent form that the animal attains while yet young, that the earlier zoologists believed them to quit the egg in this condition. For when Bosc took in mid-Atlantic the small animal which he christened *Zoe*, he never for a moment thought that it was the young of some other form.

It was in 1802 that it was first described, and ranged by the author between the *Branchiopoda* and *Amphipoda*. But Latreille, in the first edition of the 'Règne Animal' of Cuvier, placed it at the end of the *Branchiopoda*, between *Polyphemus* and *Cyclops*, while expressing an opinion that it approached nearly to the Schizopoda.

Leach seems to have held this same opinion, for without giving his reasons, he placed it at the end of the legion of Podophthalma, by side of *Nebalia*.

Desmarest, in his 'Consid. sur Crustaces,' places it in the order Branchiopoda, near *Branchipes*, while Latreille ranks it with "*Monocles*," while Milne-Edwards ranges it, with doubt, at the end of the Decapoda, with other questionable genera, after the Schizopoda, and before the Stomapoda.

In 1830 Vaughan Thompson took a zoœa in Cork harbour that while in his possession passed into the Megalopa stage, which induced him to assert that zoœa was nothing more than the larval stage of one of the crabs common to our shores.

This idea was much doubted by the naturalists of the day, more

especially Milne-Edwards, Latreille, and Westwood, as the idea of any metamorphosis in the development of the Crustacea was contrary to preconceived opinions, and to the careful and very complete observations of Rathke on the development of the embryo in the common crayfish of Europe (*Astacus fluvialis*).

The articles of Milne-Edwards in the 'Dictionnaire Classique d'Histoire Naturelle, and the remarks of Latreille in the 'Cours d'Entomologie,' were followed in 1835 by what appeared at the time to be an exhaustive discussion of the subject by Mr. Westwood. His observations were carried out upon the ova of some land crabs, that were living in the Zoological Gardens, with an exactitude and care that has left little to be added. Mr. Westwood's memoir was published in the 'Philosophical Transactions of the Royal Society,' and he received the honour of the Society's gold medal for what, at the time, appeared to be a complete refutation of Mr. Vaughan Thompson's theory of metamorphosis in Crustacea.

It is, however, a very remarkable coincidence, that the same volume of the 'Philosophical Transactions,' 1835, that contains Mr. Westwood's communication on the absence of any morphology in the progressive development of the *Gegarcinus*, also published a memoir of Mr. Vaughan Thompson on the larva of the Cirripedia, showing not only that a very extensive form of morphology takes place, but demonstrating conclusively that they are crustaceous animals, and bear no relation to the mollusca among which they previously had been generally classed by naturalists.

From this time until the present, the young form and development of these animals have been of the foremost interest in marine zoology.

In 1839 Capt. Du Cane sent to the British Association, and published in the 'Annals of Natural History,' a communication on the forms in which the young left the egg in the common prawns and shrimps of our coast. And soon after (1852), Mr. R. Q. Couch gave an account at the Dublin Meeting of the British Association of the form in which the young left the ovum in the common crawfish (*Palinurus vulgaris*) of our seas. In each of these the form so differed from one another, and from any of the others, that it began to appear as if the young of every genus in the Crustacea left the egg in a larval form, different in character.

This view appears to receive much strength from the development of the larva in Mysis, although many of the changes which this animal undergoes are those of a subembryonic rather than a larval condition, since they take place previously to the animal's becoming an independent creature. An elaborate account of the development of this animal is given by Van Beneden, in his memoir on the littoral animals of Belgium.

Since then, the crowning interest was given by Dr. Fritz-Müller, when he captured a small crustaceous animal in the high seas which in general form corresponds with the small entomostracous genus known as *Nauplius*. This he pronounced to be the early condition in which some of the prawns, and especially Penæus, quits the ovum. Some naturalists accept this hypothetical discovery as conclusive, while others more cautiously consider that the evidence Fritz-Müller has received is not sufficient, the more especially since several genera of prawns are known to quit the ovum in a more advanced form. (Pl. V., fig. 1.)

It should be remembered in the reporting on this discovery of Fritz-Müller, that first it has not been taken in connection with the parent, second, that it has not been traced from the nauplius to the zoœa condition, and lastly, has not been traced by Müller beyond the Schizopod

stage, hence its connexion with Penæus has not been demonstrated at either extremity of the chain of evidence.

The little creature, according to Müller, is rather opaque and of a brownish colour, darkest towards the extremities of the appendages.

It is by these little appendages that the young animal swims, lashing the water and working its way upwards to the light.

The first change that is observable is that it becomes slightly larger, and the terminal part projects into two pointed processes, terminating in the two long caudal hairs which were previously present, and to which others less important have been added. The number of hairs on the natatory appendages have also increased.

At this stage the form of the carapace is first indicated in the presence of a transverse line. In this we perceive an important variation from the forms of either the Cirripedia or decapod Crustacea, and moreover contrary to that of the Euphausia as illustrated by Metschnikoff.

In the youngest forms of Decapoda and Cirripeds the carapace is defined from the earliest stages.

In Lophogaster, according to Sars, the development resembles that of Mysis. The form of the embryo is more annulose and the formation of the great dorsal shield is more progressive. According to Fritz-Müller the development of the carapace in the young of Penæus is upon the same plan, and is first detected by the presence of a line immediately behind the third pair of appendages. In the anterior pair may now be seen that which after the next moult Fritz-Müller takes to be the first pair of antennæ. The second pair becomes the second antennæ, and the third pair becomes the mandibles: close to which a large helmet-shaped protuberance, which is taken to be the homologue of the anterior labrum, is present. In this early stage Dr. Müller sees within the third pair of appendages the mandibles with a prominent acute tooth and a broad transversely furrowed masticatory surface, and he says that the mandible must bear a non-setigerous appendage. Posterior to these three pairs of lobes, the embryonic condition of the future oral appendages make their appearance; the eyes still continuing to be represented by a solitary central organ.

The rudimentary appendages exhibit within the sacs the presence of hairs, which induced Dr. Müller to believe that after the next moult the animal will pass into the Zoœa stage. But here the progressive link is broken in his researches, and there is nothing to demonstrate that this *Nauplius* form passes into a Zoœa stage more than the young of Mysis does.

Previously to the time that Müller found his Nauplius, Professor Sars (1862)* studied the development of *Lophogaster typicus*, a Schizopod belonging to the family *Euphausidæ*, and this he states to be precisely similar to that of Mysis.

In 1871 Metschnikoff communicated to 'Zeitschrift für Zool.' his observations on the young of Euphausia. The first specimens he found in the open sea, and hypothetically assumed that they were the young of Euphausia, although they were not in any way connected with the parent, and had undergone one or two changes of form since quitting the ovum. He says: "I was yet convinced that it by no means represented the earliest larval form as it escaped from the ovum. I could only hypo-

* Archiv. des Sci. Phys. et Nat., tome xxi., p. 87, and An. Nat. Hist., vol. xii., 1864, p. 461.

thetically point to a six-legged transparent Nauplius as to the earliest larval condition of Euphausia. This supposition has since been confirmed by the examination of a considerable number of free-swimming Euphausia larvæ. Besides the larvæ, which were in various stages of progress, I fished up, he says, some ova from which I procured some Nauplii of the youngest form, but as my observations on the embryonic development of the Schizopoda have not been concluded, I shall only describe the ovum containing a mature larva." (Pl. V., fig. 2.)

"The ovum is a complete ball, in which one can distinguish two membranes. Between the exterior membrane—the extraordinarily delicate Morion—and the inner, the yolk skin, is a fluid clear as water, which I have also seen in the ova of Penæus. The yolk skin covers closely the now quite mature and highly transparent larva, which latter shows three distinctly developed pairs of extremities. Through the movements of the larva the egg-membranes are torn, and there escapes a peculiar animal, on the oval body of which three pairs of appendages are attached which exhibit the peculiarities of the Nauplius form of Crustacea."

"The first pair is simple, while the two others are branched and articulated into three joints, *i.e.* two basal and the terminal; the only existing opening is the oral aperture which is in the median line between the base of the third pair of appendages. It appears in the form of a very small hole which leads to a narrow œsophagus. With the exception of red tint on the ventral surface, the larva is otherwise colourless and transparent, and it is with much difficulty that some of the interior organs can be distinguished."

Herr Metschnikoff was able to trace some of the early changes, and was in hopes to be able to remove some of the objections against Fritz-Müller's treatment of the development of Penæus. He tried to follow the various alterations in the same specimen, but failed to keep the animals alive after a short period in his vessels. He was however here enabled to trace the changes which conduct, he says, the larva "into that condition which Claus has already described," but remarks that all the forms examined by him lost with their moulting the indented or crenulated margin of the carapace, which shows that he had to do with another species than *Euphausia Mulleri* of Claus. He concludes with saying that he "must draw attention to a phenomenon which is common to the Nauplius stage of Euphausia and Penæus, the contemporaneous formation of the several pairs of appendages succeeding the larval and swimming feet." "It is," he continues, "remarkable that such a mode of formation is not observed in any Entomostraca which have been developed through the Nauplius metamorphosis. I have examined in this relation the Cirripedes and Branchiopoda, and became convinced that in these crustacea the maxillaries are developed apart from the other appendages, as has been shown by Claus to be the case in the Copepoda."

Professor Claus has given the subject his attention, but his researches, like those of Fritz-Müller, were carried on upon specimens taken in the high sea, without any immediate clue to the parent from which they derived their origin.

It is certainly remarkable that so advanced an observer as Professor Claus should have been content to have drawn his conclusions from such incomplete and unsatisfactory data, particularly as he considers that an imperfect appreciation of the development of the Crustacea has occasioned in recent days the supposition relative to the genetic relationship of

insects, and as a further consequence to considerable inquiries about the origin of Crustacea.

The importance of obtaining accurate knowledge of the relationship of the young and immature forms with those of the adult animals, is exemplified by the numerous speculative theories which have arisen and depend upon the correctness of Fritz-Müller's discovery.

Claus, in his 'Crustaceen Systems,' says that Fritz-Müller even believed that he found in the Zoæa of Crustacea the origin of the insects, and very soon this view was made use of by others for the Arachnoidea.

"Anton Dorhn," says Claus, "has endeavoured by peculiar reasoning to prove the Zoæa form to be a stage in the development of the Entomostraca, and sought to show that the Phyllopodes, Ostracodes, and Copepoda have once passed through a free Zoæa stage during the phylogmatic development."

Claus distinguishes two more typical stages in the metamorphosis of Crustacea between *Nauplius* and *Zoæa*, which he distinguishes by the names of *Metanauplius* and *Protozoea*; but as these are given to stages in the progress of development rather than to forms that represent the stages as they leave the egg and become free creatures, I doubt if this addition to the nomenclature will ultimately be found to prove convenient. He moreover contends that of all Crustacea now existing that of the Phyllopoda is most probably that which bears the nearest resemblance to the primordial type, and that *Nebalia* and *Branchipus* most nearly approximate the earliest representations.

In the *Schizopoda* and *Peneidæ* the larva he asserts is hatched as a *Nauplius*, and undergoes its further development in free life; the rest of the Caridea go through the Nauplius and Protozoæa stages within the ovum, and that the first stage of free life is that of the Zoæa, mingled with features of the Mysis-like stage. The Thalassinidæ and Paguridæ are hatched in the Zoæa stage.

In the course of his researches Dr. C. Claus has determined the early forms of *Leucifer* and *Sergestis*, neither of which, although Schizopods, pass through the Nauplius condition, and Professor Sars says that *Lophigaster*, one of the *Euphausidæ*, develops its young as *Mysis*. And we know from actual observation that the young of the Anomura leave the ovum in a form little distinguishable from the Zoæa of the Brachyura, and in a more advanced condition.

It is desirable in a Report which is intended to record the present state of our knowledge of the subject, to define clearly what is understood by the several names applied to the larvæ of Crustacea according to the form in which they quit the ovum.

Here I feel it a duty to protest strongly against the terms larva and pupa which have of late been much introduced into the study of carcinology. They are the more objectionable at this present time when there is a desire to trace the connection of one class of animals with another, inasmuch as the terms are likely to convey the idea of a closer approximation by the resemblance of the nomenclature than may exist in natural phenomena. The term larva is suggestive of the grub or caterpillar condition in which insects leave their ovum, but as the condition in which the young of the Crustacea varies in form and degree, is not only different in families but in animals that might be classified as belonging to the same genus, as is the case in *Crangon vulgaris* and *Crangon boreas*, but for the different stages in which the young are hatched.

For the term pupa I believe that Mr. Darwin is mainly responsible. He having introduced it in his monograph on the Cirripedia, when there appeared to be a great change in the progressive growth of the young which was thought to equal the metamorphosis of insects, if not to represent it in kind.

I therefore propose to substitute the term Brephalus (from βρέφος, infant: αλς, sea), or young marine animal, for the term larva, while that of "pupa" had better be suppressed. Seeing that the development of the animal is gradually progressive, there is no stage or state of the animal which can be represented by it.

In this Report, whenever used, the term *brephalus* will mean the form of the animal as it quits the ovum, no matter whatever stage of development it may represent.

The several terms used for the young animal in its separate stages have been taken from animals which had been previously described as adults. These are, Nauplius, Zoœa, Phylosoma, and Megalopa. Each of which is now recognised as being a stage in which the *brephalus* quits the ovum, and therefore one in the development of the Crustacea. To these must now be added those of Metanauplius and Protozoœa.

The term *nauplius*, as representing one of the stages in which the embryo of the Crustacea quits the ovum, was introduced by Fritz-Müller in 1864, in consequence of his having taken a small crustacean that while in general form it resembled the entomostracan genus *Nauplius*, yet exhibited unmistakable evidence of being the young of some macrurous decapod: which he believed to be that of *Penœus*.

Metschnikoff has announced that the *brephalus* of *Euphausia* is in the form of *nauplius*, while it is known to be that of all the cirripedes as well as most of the entomostracous Crustacea, but these last, excepting *Branchipus*, differ from the typical Nauplius in having but two pairs of free appendages.

The *nauplius*, as it quits the ovum of the Malacostracous parent, is an animal of an ovate form, having three pairs of free appendages, the first of which is unibranched while the other two are biramose, and a single ophthalmic spot or imperfect central eye, and a strongly projecting labrum or anterior lip.

This is the state in which Euphausia (Plate V., fig. 4) is hatched according to Metschnikoff; and Penæus according to Fritz-Müller. (Pl. V., fig. 1)

Shortly after it has become a free swimming animal it moults its external skin, and with each successive exuviation it advances a stage in development, its first apparent advance is in the appearance of lobes that ultimately become the appendages of the mouth. Metschnikoff remarks that this phenomenon is common to the nauplius of *Euphausia* and *Penœus*, that is, the contemporaneous formation of several appendages succeeding the three original pairs of swimming feet.

He says moreover that it is remarkable that such a mode of formation is not observed in any of the Entomostraca which have been developed through the nauplius metamorphosis.

It is this stage for which Claus has suggested the term *Metanauplius* (Pl. V., fig. 2), while that for which he proposes the name of *Protozoœa* is when the pleon is developed, but neither the pereiopoda or appendages of the pleon are present. (Pl. V., fig. 3.)

But here we have so close an approximation to the Zoœa as it leaves the

ovum of the Brachyura, that it appears doubtful if there be any distinction between Protozoæa and Zoæa.

Fritz-Müller comprehends under the term Zoæa all those *brephali*(larvæ) that have two pairs of antennæ. The oral appendages and the gnathopoda present the latter in the form of swimming appendages. Having in view the young of the *Brachyura*, *Anomura* and *Macrura*, as well as certain stages in the development of the Stomapoda, whilst he could not include the young Schizopoda with the six pairs of legs (*Euphasia*) which Claus considers must be accepted as a zoæa form. Claus considers that there is a highly important character excluded from this definition,—the stage of the development of the pereion, or, as he terms it, the limbless central body (*Gleidmassenlosen Mittelleibes*) in contrast with the pleon (*Hinterleib*) and its appendages This is, he says, just the characteristic of the zoæa, which needs explanation, and at the same time contains the key for the comprehension of the structure of the zoæa stage of the Malacostraca. It is necessary to understand and explain the striking relation of the pereion that exists in an immature condition, and from which sprout the five pairs of pereiopoda between the cephalon, with its numerous well-developed appendages and the well-formed but still limbless pleon. He says that almost in all forms of brephalus (larva) the pereion is either completely suppressed as in the Decapoda, or appears in the form of rudimentary somites, as in Schizopoda and Stomapoda. The pereiopoda are produced later than the appendages of the pleon. "Of course," he continues, "an exception must be made for the zoæa of *Penæus*, from which the limbs of the pereion are produced previously to those of the pleon, with the exception of the two lateral appendages of the tail, which as belonging to the sixth somite of the pleon appears sooner, or at least about the same period, as those of the pereion."

In arriving at this conclusion Claus appears to have gathered his facts from too circumscribed an area. Assuming his observations on the development of *Penæus* to be correct, he has overlooked that of the typical zoæa when it quits the ovum, as seen in *Carcinus Mænas*, and that of *Stenorhyncus*, *Inachus* and *Maia*, of the latter two of which he has himself given figures that represent the pereiopoda advancing in development anterior in degree to that of the pleopoda. Moreover, the brephalus (larva) of *Homarus* and *Palinurus* have the pereiopoda well advanced in formation previously to any evidence of the pleopoda being in existence. Whilst others have them developed in a common ratio.

The zoæa of Crustacea therefore may be defined as a *brephalus* (larva) that has two pairs of antennæ, the oral appendages and gnathopoda more or less developed, but in which the pereiopoda and pleopoda are yet absent or in an immature condition.

This is the condition in which the brephalus quits the ovum as the zoæa of the *Brachyura*, *Anomura*, and some *Macrura*. But in each there is a persistent feature that distinguishes one form from that of the others, and as far as my own observations have led me precludes their being confounded one with the other.

The *brephalus* of the *brachyura* is a *zoæa* (Pl. VI., figs. 3 and 4), and the most constant as to its general type of all the families of the class. With the exception *Gecarcinus*, which quits the ovum in the *Megalopa* stage, I am not aware of any other of the short-tailed crabs that is not hatched in the zoæa condition.

That of *Carcinus mænas*, as our most common European species, may

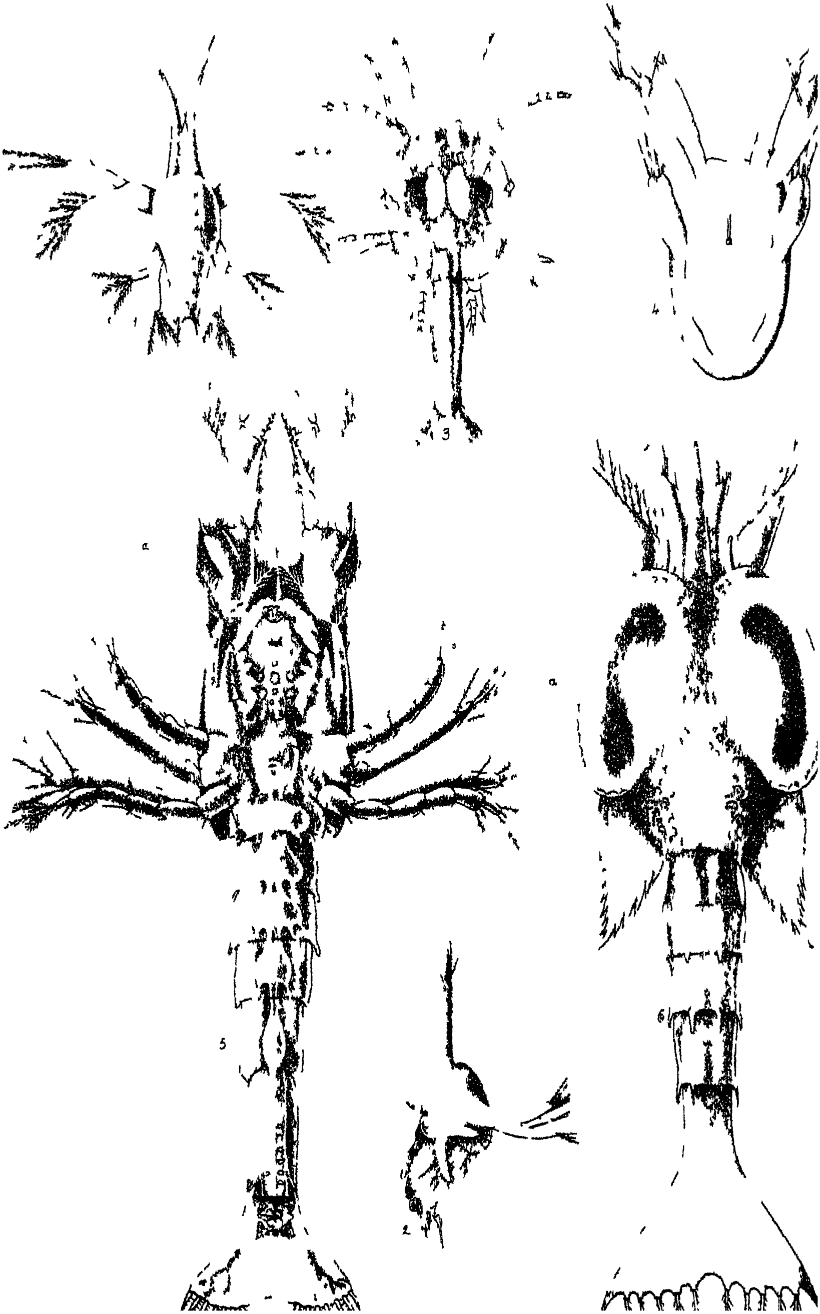
be taken as the type of zoæa. When it quits the ovum, and throws off the enclosing membrane, and swims first as a free animal, it has a distinct and well-developed carapace. It is dorsally arched and laterally compressed and rounded off at the infero-posterior angles. It is, moreover, armed with long characteristic spines on the dorsal and lateral surfaces, and anteriorly with a great rostrum, but these features vary in different genera, as shown in Pl. VI., where the two extremes are seen. In Trapezia, fig. 3, the spines are all very long, in Gelassimus, fig. 4, they are very short. The pereion is in a compressed or immature condition, and the pleon has six well-developed somites, the terminal one ending invariably in a fork-like extremity that varies in degree, and is armed with a greater or less number of strong stiff ciliated spines that differ in a constant degree so as to enable one almost to define the generic limits of species. It has invariably two pairs of antennæ, represented by the early budding condition of the permanent organ in the first pair, and by deciduous representatives in the second in the form of two long teeth or spines; the mandibles and two succeeding pairs of oral appendages; the third pair, or *tetartognathus*, being absent; while the gnathopoda are developed into large characteristic swimming appendages. Of these, which are invariably biramose, one represents the permanent and the other the secondary branch of the adult organ: in this early condition the primary or permanent branch is five-jointed, and the second three. The number of these joints represents the more or less advanced condition of the zoæa, and corresponds with the progressive development of the animal. The pereiopoda are represented by two or three small sac-like lobes, within which the several pairs may afterwards be seen to be developed.

The *brephalus* of the *Anomura* is also a zoæa (Pl. VI., figs. 1 and 2), and differs from that of the Brachyura more in general appearance than in its degree of advanced development. The anterior portion corresponds, except in the armature of the carapace, very closely with the same part in the zoæa of the Brachyura, while the posterior portion of the animal assimilates more nearly with that of the zoæa of the Macrura.

If we take the zoæa of *Pagurus* as the type, we find that the carapace is dorsally more depressed than in that of the Brachyura, and extends nearly horizontally from the rostrum to the posterior margin of the carapace, the lateral margins are not so deep, and are produced posteriorly, so as to form a prominent process or tooth on each side. This projection is very constant, but varies in degree with separate families. The rostrum also is generally prominent, and projects horizontally forwards.

The pereion is not appreciably developed. The pleon has six somites, the posterior one being long, and terminating in a broad fan-like telson, the posterior margin of which is divided into two halves by an excavation that varies in extent in different genera. Each division is furnished with fine strong ciliated spines, which stand on their own well-defined lobes, and the outer angle is armed with a short sharp tooth.

The eyes are large and ovate. The first pair of antennæ resemble those of the Brachyura, they are single jointed, and support several auditory cilia, and two ciliated hairs, one apical, and the other (the longer) subapical. The second pair of antennæ consist of a basal joint and two appendages: one is cylindrical, and tipped with two or three long ciliated hairs; the other is formed into a broad flat squamose plate, straight on the outer side, where it terminates in a strong tooth, and arched on the inner side, and fringed with numerous long spinous hairs richly furnished with cilia.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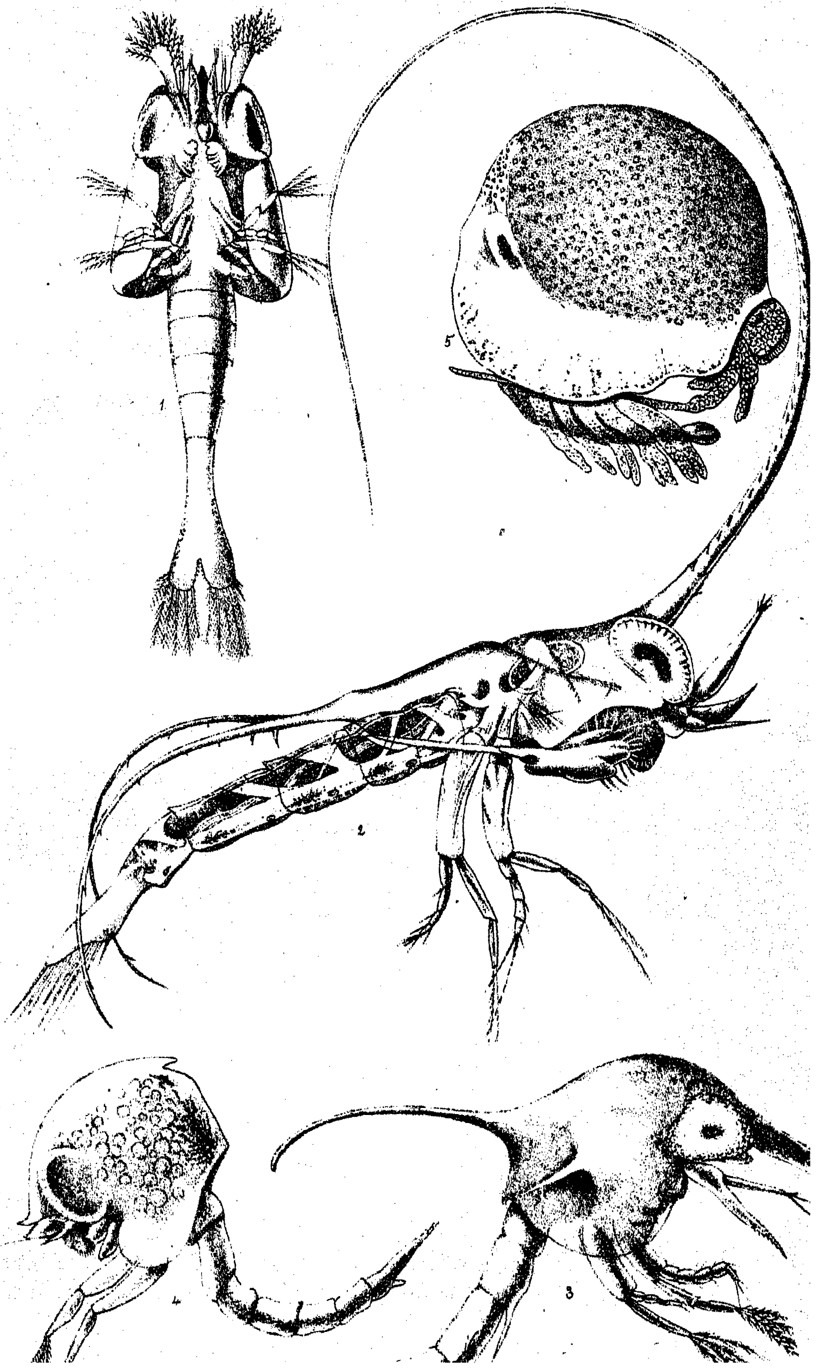
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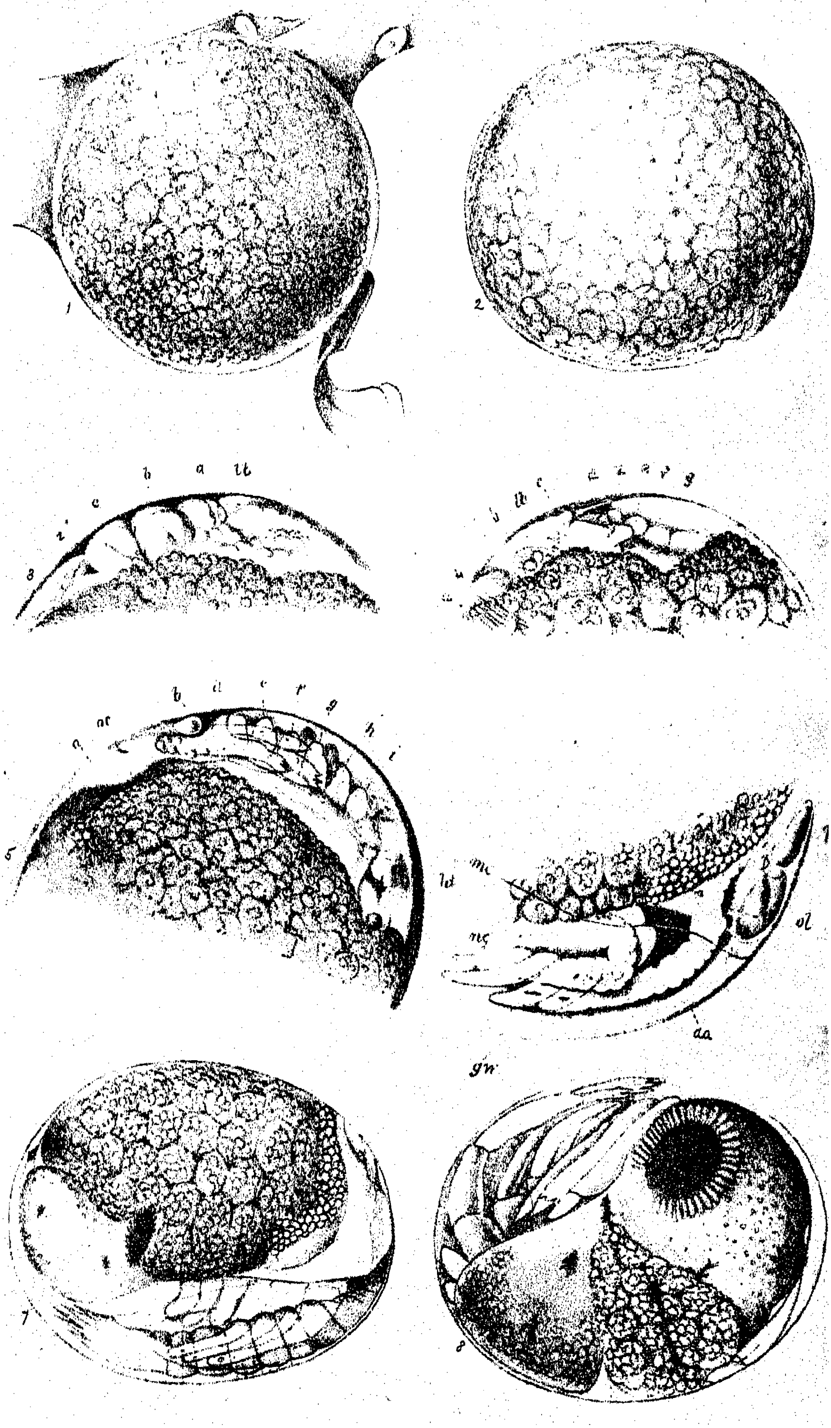


The mandibles are without an appendage. The oral limbs are assuming much of their permanent form, except the tetartognathus, which is not visible. The gnathopoda are developed very similarly to those in the Brachyura zoæa, but exhibit a joint more in the development of the primary branch of the second pair. One solitary hair, differing in length, structure, and position from the others, appears to be constant in all forms of the *Anomura* zoæa. In some species it is nearer the base of the apical joint than in others; but it is invariably constant, extremely long, and furnished with very long and delicate cilia, that are inserted at right angles with the main stalk of the hair. I do not remember having observed it on any zoæa but those of the Anomurous Crustacea.

The zoæa of the Porcellanidæ (Pl. VI., fig. 2) may readily be distinguished from those of *Pagurus* by the length of the rostrum and postero-lateral processes of the carapace, which sometimes equal the length of the animal, and sometimes half; by having unarmed spinal processes to represent the second antennæ, instead of a ciliated squamose branch, and by having the last somite of the pleon terminating in a broad flat plate, the posterior margin of which is posteriorly produced to a point, instead of being hollowed, while it carries five ciliated hairs on each side of the median line. In one species, Claus figures the termination as produced to a long spine.

The zoæa of *Galathea* (Pl. V., fig. 6) may be distinguished by the posterior margin of the carapace being definitely serrated; by two dorsal teeth on the posterior margin of the somites of the pleon; by the extremely long ovate eye occupying about one half the length of the carapace; by the presence of a sharp serrated tooth at the distal extremity of the basal joint of the second antennæ; by the shortness of the cylindrical branch that terminates in a small tooth and one ciliated hair; and the sharply pointed distal angle of the squamose branch of the same antennæ.

The zoæa of *Dromia* (Pl. VI., fig. 1), much resembles that of *Pagurus*, except that it appears to have no posterior processes at the infero-distal angles of the carapace; but more especially by the form of the telson, which is extremely deeply cleft in the median line of the posterior margin.

The *brephalus* of the *Macroura* differs very much in the character in which it quits the ovum in separate genera. Those that leave it in the zoæa (Pl. V., fig. 5) condition are very distinguishable from those of the *Brachyura* and *Anomura*.

The zoæa of the common Shrimp (*Crangon vulgaris*) may be taken as the type of the form. It differs from the zoæa of the common Prawn (*Palæmon squilla*) in very small details, one of which is in having a pointed rostrum that it loses with the second moult.

The carapace, long, narrow and moderately compressed, furnished with a slender rostrum projecting horizontally forwards, having no projection or tooth along the posterior and lateral margins.

The pleon consists of six somites, of which the last is expanded into a flat membranous plate, slightly indented in the median line of the posterior margin, and fringed with six ciliated hairs, and one, the external, small spine-like point.

The eyes, *a*, *a*, are large, and obliquely ovate.

The first antennæ, *b*, *b*, are two-jointed; the basal joint is long and cylindrical; it supports at the outer distal angle a stiff ciliated spine, and at the extremity the second branch, which appears in the form of a small uniarticulate joint, out of which near the extremity another seems ready to

bud, supporting at its apex a crown of auditory cilia, and one short ciliated hair.

The second antennæ, *c*, *c*, consist of a peduncular basal joint, supporting two branches; the internal gradually narrows from the base, and terminates in a long spine-like hair fringed with cilia; the external is in the form of a squamose plate, the external margin of which is straight, and the internal becoming broader from the base, and then rapidly running to an apex; the inner oblique distal margin being fringed with ciliated hairs. The mandible and oral appendages are well formed, each assuming an approximation to the adult condition, except the posterior, or *tetartognathus*, which assimilates to that of the gnathopoda, the character of which it partakes. In each, the number of joints in the primary ramus has increased to six, and the pereiopoda exhibit evidence of rapid development, in the form of cylindrical pendulous sacs, which decrease in length posteriorly.

There are slight variations from this form in different genera.

In *Palæmon* the primary branch of the gnathopoda have but four joints, and terminate in stiff short spine-like hairs; while in *Crangon* the hairs are long, flexible, and ciliated. This latter is the case with the zoæa of *Alpheus* and *Stenopus*; while in that of *Hymenocera* the character is more in accordance with *Palæmon*.

The zoæa in these orders respectively, *Brachyura*, *Anomura*, and *Macrura*, while they differ from each other, yet possess characters that are generally common to two. The form of the carapace in the zoæa of the Brachyura, with its great dorsal spine, which although in some genera, as *Gelassimus*, *Libinea*, and *Menœtheus*, it is much reduced, so that in the last it is a mere prominence, is still a feature peculiarly characteristic of the zoæa of the order. Next to which are the great spines on the lateral walls of the carapace. The presence of these is not so constant, but they are never seen on the carapace of any zoæa in either of the other two orders.

In the *Anomura* great lateral spines, and sometimes smaller spines, project from the posterior margin of the carapace; these, together with the rostrum, more or less important, is a feature peculiar to this order, and from my own knowledge I am not aware of any exception to this rule. But Claus, in his work so frequently quoted, has given the figure of one that has all the characters of the zoæa of the *Anomura*; but he calls it an "Erichthina larva" (Pl. IV., fig. 1), but adds, "Nach Willemoes-Suhm die Larva von Leucifer;" but certainly it bears no resemblance to the young *Erichthina* as it quits the ovum of the adult *Squilla*. Another feature that especially belongs to the zoæa is that of the terminal somite of the pleon, or telson. It is always forked in the Brachyura, and the few cases in which the terminal spines are short, still retain a distinct and characteristic feature of the group.

In the zoæa of the *Macrura* the carapace is free from spines or processes, and the terminal somite is flattened out into a broad thin fan-like plate, divided in the median line by a more or less defined emargination.

Now, if we compare the zoæa of the *Anomoura* with these two groups, we shall find that the tendency is to class them from their general form with the zoæa of the *Macrura*. And this, without exception, includes the Porcellanidæ, Dromidæ, and other depressed forms, as well as the Paguridæ. And the stage in development of the antennæ exhibits an approximation to the *Brachyura* zoæa only in the first pair, while in all the other appendages the *Macrura* features prevail.

It would therefore necessitate, if the *Anomura* be excluded from its place in the classification of the Crustacea as a sub-order, as suggested by Claus, that it should go over to the *Macrura* as a whole, including the genera *Dromia* and *Galathea*. But it appears to me that if Claus' figures be those of *Albunea* (*Crustacean Systems*, Pl. IX., figs. 1–10), as he thinks probable, the evidence is strongly in favour of the retention of the sub-order, for the broad fan-like telson is suggestive of an internal Anomurus structure.

It would appear, therefore, the evidence is much in favour of the argument that the development of Crustacea shows there is a group of zoæa between the two well-defined orders that exhibit features that belong to it, and are not common to the others; and these features show an advance in the development of the crustacean embryo before it quits the ovum.

The nearest form of crustacean life to the zoæa when it quits the ovum, appears in the young of *Squilla*, which has long been known by the name of *Alima*. The advancement in development is shown in the distinctly pedunculated character of the eyes; in the articulated condition of the peduncle and the two distinct branches of the first pair of antennæ; in the character of the gnathopoda, which assumes a resemblance more distinctly typical of the adult feature; and in the advanced development of the four posterior pairs of perciopoda.

Alima is more advanced in development when it quits the egg than zoæa, but not so much so as the young of the genus *Homarus*, which is developed in what Claus and Fritz Müller have named the *Mysis* stage; that is, the appendages of the cephalon are well advanced towards their adult form, and those of the pereion carry a secondary branch, or ecphysis, attached to the third joint or ischium of each pair of pereiopoda.

But in this last-named genus we find that some of the pleopoda are present; and the curious phenomenon exists, that, while an enormous amount of development has gradually proceeded to such an extent that all the appendages are rapidly assuming the permanent type, those of the pleon, which in some genera are in advance of those of the pereion, in *Homarus* remains in abeyance, and appear not to have progressed beyond the zoæa stage.

This curious fact is exemplified more decidedly in the genus *Palinurus*, where the pleon appears to be in a still more embryonic condition, while the cephalon and pereion are distinctly pronounced, in a parallel condition with that of *Homarus*, from which it differs most apparently in the length of the pereiopoda in *Palinurus*, and in the absence of the chelate character of the first pair of pereiopoda.

In the young of *Crangon boreas* (Phipps)—which naturalists have been divided in opinion as to whether it should be embraced in the same genus with *Crangon vulgaris* or not—the young is advanced in development beyond the condition of the zoæa as it is in *Crangon vulgaris*. It quits the ovum with all its appendages conspicuously advanced, whether they belong to the cephalon, pereion, or pleon. This we find to be also the case in the genus *Thalascaris*, an undescribed deep-sea genus belonging to the *Challenger* collection of Crangonidæ.

A still further advance is found in a form closely allied to *Alphæus*, that I believe has been recorded as a species, but which I described in the 'Transactions of the Royal Society' under the generic name of *Homaralphæus*, on account of its resemblance in the adult form to *Alphæus*, and in its young to that of *Homarus*.

A deep-sea genus, closely allied to that of *Axius*, that I have named *Eiconaxius*, taken during the *Challenger* cruise in the Eastern seas, has the same advanced condition of the embryo, and shows that the *Megalopa* stage exists not unfrequently in marine *Macrura*, although we have previously had no evidence of it.

The fresh-water genus *Astacus* (Pl. VI., fig. 5) and the land crab *Gecarcinus*, long since made known to us, the former by Rathke, and the latter by Westwood, leave the ovum in the last stage, which is that of an approximation of form to the adult animal, while it yet retains many features that exhibit incompleteness of development. This is most apparent in those parts which show a tendency to depart from the characteristics of the order to adapt themselves to constitutional requirements; as, for instance, the adult *Alpheus* mostly lives in dark places under stones, groping in mud and in such like spots at the bottom of the sea at a few fathoms deep. To suit this condition of things, it is highly convenient to the animal that the eyes should be protected; and since the peculiar habitat of the animal is that of dark holes, those in which the eyes are least improved by use are as suitable to its existence as others; those which are protected and least liable to injury become the kind most adapted to survive.

Thus it follows, that while the rest of the animal advances in growth the eyes remain in abeyance, and the anterior margin of the carapace extends beyond and overlaps them, thus affording protection, and by its tenuity admitting a sufficient amount of light for the purposes of the animal's requirements. Thus it appears that the development of *Alpheus* shows a relative retrograde character in the progress of the eyes to that of other parts. So again, in the comparison of the pleopoda in the Brachyura in the adult with those of the *megalopa* stage of the same animal, we find that of the younger framed upon a simple type adapted for swimming, while in the adult it is altered to suit other purposes—in the female to support the gravid ovum, and in the male those of the anterior to assist in copulation, while those of the posterior are more or less rendered obsolete in consequence of the absence of any duty to fulfil.

The study of the several forms in which the embryo quits the ovum in Crustacea is, I believe, very instructive, as bearing on the tendency of variation of forms in adult animals.

From the earliest forms to that of the most perfect, in which the brephalus quits the ovum, there is a series of stages in which the embryo appears ready to take upon itself the conditions of a free and independent animal. This capability does not appear to be connected with any particular adult type, or conditions of existence, but exists in closely allied species and genera as well as in those that are extremely distinct: neither does it appear to bear any relation to the more or less advanced character of the several genera.

The following list is the order of the various stages of development, when the brephalus quits the ovum, together with the adult form from which it is derived.

1. Nauplius....................Euphausia (Metschnikoff), Penæus? (F. Muller.)
2. Meta-nauplius ....None.
3. Proto-zoæa..................None.
4. Zoæa ....Brachyura, Anomura, and some Macrura.
5. Phyllosoma ....Palinurus.
6. Megalopa ....Astacus (Rathke), Gecarcinus (Westwood).

In this list the earliest or nauplius form belongs to Euphausia, or the lowest stage in the classification of the adult animal; while the next stage, or zoæa condition, belongs to all the higher forms with the exception of one genus only among the Brachyura, and some of the Macrura. To these belong the phyllosoma and megalopa stages.

Before we can conclude our report on the development of Crustacea, it is desirable that we should examine the earlier stages of the embryo, as well as the character of the various ova in relation to the adult forms.

The eggs of Crustacea vary in size in different genera and sometimes in form, but not very much in this latter feature, never more than from round to oval and egg-shaped. But in size the variation is greater, and this not in relation to the proportion of the animal; for *Palinurus*, which is two feet long, has the ovum only one-quarter the size of that of *Astacus*, which is only three inches long.

Some idea may be gathered by the following list of the diameter of the eggs of the animals that have been examined; that are from the ovum of the fresh-taken animal and from specimens preserved in spirits.

Crangon ...... $\frac{1}{40}$	Thalasscaris ...... $\frac{1}{10}$	Palæmon ...... $\frac{1}{40}$
Cr. boreas ... $\frac{1}{8}$	Arctus .... $\frac{1}{50}$	Palinurus ...... $\frac{1}{60}$
Homarus...... $\frac{1}{10}$	Astacus .... $\frac{1}{8}$	Willemæsia ... $\frac{1}{16}$
Carcinus ...... $\frac{1}{20}$	Cancer .... $\frac{1}{30}$	Pagurus......... $\frac{1}{20}$

The ova are attached to the pleopoda of the mother in all forms of Decapod Crustacea by means of a membranous filament that varies in separate genera. In *Palæmon*, it is very thin and transparent, and differs from that of the Brachyura and other forms. It is not easy to determine its origin, but there are connected with it, as if incorporated in the structure, certain epithelial-like cells, that in form and appearance resemble those that Mr. Alfred Sanders has figured as living zoosperms belonging to *Palæmon Squilla;* they are much larger and appear as if flattened, and absorbed into the surrounding structure, which spreads out to an extreme tenuity, and encompasses the entire ovum, which it holds and suspends. In some genera it is exceedingly slender and delicate, and easily ruptured; in others it is strong, fibrous, and not easily broken.

The observations that I have made have generally been on the most common forms that I could procure alive, such as *Crangon*, *Palæmon*, *Homarus*, *Astacus*, *Palinurus*, *Portunus*, *Carcinus*, and *Cancer*. The two first of these are very suitable for examination from the beautifully transparent nature of the vitellus; while those of *Homarus* and *Astacus* afford advantages from their large size.

The ovum is generally round, but in some species, as in *Palæmon*, they afterwards become somewhat oval. (Pl. VII., fig. 1.)

The yolk in most instances fills, or nearly fills, the egg: but in some cases, as described by Metschnikoff, there is a tolerable space between the membrane that encloses the vitellus and the chorion. This he states to be the case in the ova of *Euphausia* and *Penæus*, and I have observed that the same condition exists in the ovum of the genus *Nika*. This space is filled by a clear and slightly viscid fluid. At first the yolk consists of numerous minute cells, very uniform in size, that appear to have little or no cohesive property to each other. Taken separately, they appear to be tolerably transparent, but in the aggregate they assume a colour that is peculiar to each genus. In some the colour of the vitellus is grey, in others yellow, orange, brown, green, and purple. Shortly the mass of

the vitellus appears to divide into larger masses, each mass being the congregation of a number of cells adhering together by compression, as if the cells had increased in size and with the increase enforced a corresponding pressure against each other; each cell, moreover, contained within itself a number of smaller ones.

The vitellus at a not very distant period becomes transparent, according to our observation, at one spot (Pl. VII., fig. 2*a*) on the margin. When viewed laterally, it appears like a line of clear fluid near the chorion, while the cells of the vitellus that are in contact with it have become large and transparent, but tolerably even along its margin. This line extends along the surface and deepens towards the centre. Later and closer inspection shows that this transparent region extends to some depth below the surface, and continued examination demonstrates that it is progressive, so that the vitellus, while united at one point, is so deeply divided at the opposite, that it appears to cover the embryo on each side. Soon the cells appear to congregate together into lobes and film over with a skin of extreme tenuity; but these lobes, *a*, *b*, *c*, upon inspection are repeated on each side, while a central one occupies a space between them, while another, more important, is also apparent in the same line; all these are, at this stage, nearly equal in progressive development, the two central being perhaps the largest, certainly the longest. (Pl. VII., fig. 3.)

Soon after, three or four smaller lobes are seen to be formed in a continuous line with the preceding marginal ones, at this early stage the last-named central lobe may be observed to divide into two equally prominent ones at its extremity. A little later and all the several lobes become clearly defined. The four latest pairs that appeared are less massive than the three previously existing pairs, and the whole, even at this early embryonic stage, may from their relative position and arrangement be detected in their connexion in the advanced embryo. (Pl. VII., fig. 4.)

The three pairs of lobes that were first brought into existence are more massive and globular in their appearance. They are marked *a*, *b*, *c*, in the figures, and very soon may be observed to assume definite forms. The first (*a*) is rather long and compressed. The second (*b*) globular at one extremity but apparently extended at the other; while the third (*c*) is extended and bilobed at its extremity. Under a slight compression these distinctions of form become readily appreciable to observation.

It is within our power to determine with confidence at this early stage that these three pairs or sets of lobes occupy the position of the future organs (*a*) of vision and antennæ (*b* and *c*). The great central lobes that separate them, and which in the decapoda approach each other, correspond, the one to the labrum, the other to the terminal extremity of the animal; and the three or four smaller lateral lobes (*d*, *e*, *f*, *g*) that appear a little later correspond with the oral appendages of the future animal.

Having ascertained in this incipient condition the relation of the first group of three anterior pairs of lobes to the appendages of the adult animal, and observed how closely these lobes correspond with each other at first, and how they vary and become distinct from the succeeding,—a distinction that is suggestive of their being a separate group of appendages,—leads to the conviction that they correspond with the three anterior pairs of appendages in the earliest or nauplius form of Crustacea, as they exist in the *brephalus* of the Cirripedia.

To strengthen this idea and give it demonstration, take the small dark

spot that is considered to be an imperfect organ of vision. The ophthalmic spot is visible at this period in the embryo. (Pl. VII., fig. 5.)

If we follow this examination through succeeding periods, we find the progression of the development of the embryo to be distinct and continuous, and the changes important and reliable. The small ophthalmic spot is present and the two central lobes are still in apposition, but have become more elongated. The first (*a*) of the lateral lobes has enlarged and become more massive and consolidated in structure. The second and third (*b*, *c*) have increased very considerably in length and lost the lobe-like appearance, putting on that of more extended appendages; whereas those of the three succeeding pairs of lobes still retain their simple lobe-like character. (Pl. VII., fig. 5.)

The several parts are now becoming very distinguishable in their relation to the rest of the animal, and it is interesting as well as instructive to examine the nature of the structure in detail.

The first or most anterior pair of lobes, *a*, meet together at the anterior extremity, at the union of which the ocular spot is visible, while they are separated at the opposite by the intervening central lobe which we have already determined to be the labrum (*lb*.) The entire mass differs from the other portions of the embryo by being of an opaline and less transparent appearance. It is formed by an aggregation of exceedingly minute cells that appear to cohere closely together; these lobes appear to be continuous with a great central mass that extends from one extremity of the animal to the other. Soon we perceive some pigment cells forming a small, dark, irregular stripe deep within the anterior lobes, *a*, and by its arrangement apparently separating off a portion of the great opaline mass. (Pl. VII., fig. 5.)

This stripe of pigment is the early or incipient condition of the great black cornea that is so conspicuous an object in all young Crustacea. At the same period, near the opposite extremity of the ovum a small and irregular pulsation may be observed. This is the position of the future heart. At first the pulsation is very slow, feeble, and irregular; a small corpuscular body may be seen jerked forward and backward within a small saccular space or hollow, after unequal intervals of rest. After a time a solitary corpuscle is seen to burst through an opening in the walls of the sac. This at distant intervals is repeated, and after a time more frequently, until in a day or two the throb of the sac becomes more constant, the presence of the corpuscles more numerous, and the flow of them increasingly more regular and continuous.

The vitellus has now decreased in size, but not to any very considerable extent externally, but is gradually decreasing internally. At the opposite extremity to the anterior lobes of the embryo, the margin of the vitellus may be observed as having broken into a series of very even cells (Pl. VII., fig. 6), transparent in colour and regular in position, forming two or three very decided rows, until they gradually disappear in the undeveloped structure of the vitellus.

The external surface of these several rows of transparent cells appears (Pl. VII., fig. 6) to be enclosed by a membrane of extreme tenuity, that is evidently connected with and forms the outer walls of the alimentary canal, *al*. The marginal cells appear to build up the fibrous structure of the walls, while certain small particles of granular waste (*gw*) matter fall into the central passage. Here they exist as foreign bodies of not any large amount, and lie enclosed within a cavity of their own making;

within this cavity the small particles of opaque irregular granulose matter move forwards and backwards with an uneven movement corresponding to an irregular contraction of the walls of the alimentary canal.

When this organism is so far advanced as to extend to the region beneath the heart, it exists continuously to the terminal extremity of the pleon, and the great dorsal artery, *da*, may be distinguished leading directly from the heart to the terminal extremity of the animal, just beneath the dermal surface of the embryo as it lies in close contact with the chorion of the egg. The heart lies just beneath the dorsal posterior extremity of the carapace, the posterior and lateral margin of which, *mc*, traverses the animal just behind the heart in a slightly waved line to the eye. The antennæ have a distinctly appendicular appearance, and reach beyond the three or four succeeding pairs of lobes, and terminate, one, *b*, in a single pointed branch, the other, *c*, in two branches terminating in a serrated extremity.

The oral appendages have not much departed from the lobular condition, but three other pairs, which appeared behind them, have enlarged and are rapidly increasing and become double-branched. At the base of these appendages the great opaline mass, *ng*, may be seen extending, being apparently doubled on itself, just behind the last pair exhibited, but in reality following the inflection of the ventral surface of the folded embryo. This continuous opaline mass may now readily be determined to be the embryonic condition of the nervous ganglia.

The several parts from this time rapidly and regularly progress in the development of their structure. The ophthalmic lobes gradually appear to increase in condensation, every cell exhibiting a distinct but not very opaque nucleus. The larger and rounder cells are nearer the periphery, those that are deeper become compressed into angular shapes, while those that are nearest the cornea arrange themselves in columnar masses, most distinct towards their base.

The antennæ lie folded backwards along the margin of the carapace. The mandible is directed inwards, and is invariably a single lobe, while the two succeeding oral appendages are bilobed, with a tendency to break up into more divisions. (Pl. VII., fig. 7.)

The development of the pleon is completed, as far as its external and internal parts are apparent, at the period when the development of the heart is advanced so that it is enabled to pulsate. The remainder of the period necessary for incubation appears to be devoted to the completion of the anterior appendages, and that of the internal viscera. (Pl. VII., fig. 8).

The vitellus is continuous with the development of the animal, and exists in an inverse ratio with that of the growth of the embryo. When it is entirely converted, the growing form has progressed as far as it is capable through internal forces. To add to its further development, it is necessary that it should obtain a fresh stimulus from agencies beyond its own organization. Its vitality has advanced as far as it is capable, and it forces its way by the rupture of the egg-case into other conditions.

As a free animal, the brephalus exists, as I have shown before, in various forms, which are probably dependent upon the length of time that the embryo remains in the ovum. For extended observation appears to demonstrate that it quits the ovum of various genera in almost every stage of its embryonic growth.

EXPLANATION OF THE PLATES.

PLATE V.

FIG. 1. Nauplius (*Brephalus*) of Penæus. (After Fritz Müller.)
" 2. Metanauplius of Penæus. (After Fritz Müller.)
" 3. Protozoæa of same. (After Fritz Müller.)
" 4. Nauplius (*Brephalus*) of Euphausia. (After Metschnikoff.)
" 5. Zoæa (*Brephalus*) of Macrura (*Crangon vulgaris*).
" 6. Zoæa (*Brephalus*) of Anomura (*Galatheæ*).

PLATE VI.

FIG. 1. Zoæa (*Brephalus*) of Anomura (*Dromia falax*).
" 2. Zoæa (*Brephalus*) of Anomura (*Porcellana longicornis*).
" 3. Zoæa (*Brephalus*) of Brachyura (*Trapezia*).
" 4. Zoæa (*Brephalus*) of Brachyura (*Gelassimus*).
" 5. Megalopa (*Brephalus*) of Macrura (*Astacus fluviatilis*).

PLATE VII.

FIG. 1. Ovum of Palæmon recently excluded.
" 2. Ovum showing incipient stage of embryonic existence.
" 3. Ovum showing the presence of the three pairs of lobes that represent, *a*, the eyes and, *b*, first and *c*, second, antennæ: as well as the labium and caudal extremity.
" 4. Same still further advanced, with four pairs of lobes, *d*, *e*, *f*, *g*, added that represent the future oral appendages.
" 5. The same still further advanced, showing those which represent the future Gnathopoda, *h* and *i*.
" 6. Section showing the forming of the embryonic heart, *ht*, alimentary canal, *al*, and ventral nervous cord, *ng*.
" 7. Embryo approaching completion.
" 8. Embryo previous to quitting the ovum.

Report of a Committee consisting of Professor ROLLESTON, Major-General LANE FOX, Professor BUSK, Professor BOYD DAWKINS, Dr. JOHN EVANS, *and* Mr. F. G. HILTON PRICE, *appointed for the purpose of examining Two Caves containing human remains, in the neighbourhood of Tenby.*

OPERATIONS were commenced in the way of the exploration of the "Little Hoyle" Cave, Longbury Bank, parish of Penally, near Tenby, on Monday, July 22, 1878, and were continued during that week and upon the ensuing Monday.

It will be well to begin our report by a summary of the results which we have attained, and in the second place to give in detail the facts upon which our general conclusions have been based.

The two caves which we here examined are contained in a peninsula of mountain-limestone known as "Longbury Bank," bounded on either side by a valley which unites with its fellow at the blufflly-ending N.E. extremity of the "bank." If we compare the levels hereinafter given with the facts spoken to by the raised beaches along this coast, and by other observations we cannot doubt that Longbury Bank was once, and that in no very remote geological period, washed on either side by the sea, and presented much the same general appearance as some of the still so

conditioned banks in the neighbourhood of Pembroke. Of the two caves examined by us, one contained no objects of special interest, and the other had been previously investigated by other explorers, viz., the Rev. H. H. Winwood, of Bath (see 'Cave Hunting,' by Professor Boyd Dawkins, F.R.S., p. 133, and 'British Mammalia,' Memoirs Palæont. Society, 1878, p. xxii.), and Mr. Edward Laws, of Tenby (see 'Journal of Anthropological Institute,' August 1877). A very considerable segment, however, of this latter cave had been left unexamined, and it has been by the examination of this undisturbed portion of the cave, and by the clearing out and investigation of the contents of all the rest of the cave, and comparison of them with the specimens previously obtained and most liberally put at our disposal for this purpose by Mr. Edward Laws, that we have been able to come to the following results.

The cave in question, known in the neighbourhood as "Little Hoyle," in contradistinction to a much larger cavern close by, known as "Hoyle's Mouth," may be divided roughly into two main segments, one beginning with a large mouth opening northwards, and extending from that mouth in a direction S. and with a sharp slope upwards up to a point distant 25 feet from the mouth; the other of about 16 feet in length, dipping downwards from that point in a S.E. direction, to communicate by a narrow hole with a wide cave mouth on the S.E. side of the bank in which bones of man, bear, and ox had been previously found by Mr. Laws. This second segment of the cave had underlaid one of those "initiatory areas of depression," to use the phraseology of the late Professor Phillips (see 'Report of British Association,' Bath Meeting, 1864, p. 63–64), which ultimately lead, and here had led, to the breaking-in of the cave's roof, and which might here be spoken of in the phraseology of the county as a "sink" or "soaker." It was filled up to a depth of nearly 10 feet with fragments of limestone, and made earth containing bones of men, domestic animals, foxes, rabbits, and oyster and limpet shells. We may speak of it hereafter as the "segment of depression."

This "segment of depression" had been scarcely touched by any explorers previously to ourselves. The longer segment of the cave, opening northwards, may be spoken of as the "north cave;" and a comparatively low diverticulum 16 feet long, branching off from it to the east, and widening from 3 feet to 10 feet for about 9 feet of its length, we may speak of as the "east chamber." This last we found by means of smoke to communicate through a narrow flue, with a small flat surface near the top of bank, which was potentially an "area of depression," but had actually been a fox-earth. Having in mind the levels and communications of the several parts of this cave, and considering in connection with them the relative proportions and conditions in which the contents of the cave, viz., (1) breccia and stalagmite, (2) red cave-earth, (3) black earth mixed with angular stones, (4) worked flint and other implements, (5) fragments of pottery, (6) ashes, and (7) bones of men and of beasts, pleistocene and other, found in the different segments of the cave, we are, on the whole, of opinion that though the main or north portion of the cave was used by man for purposes of habitation in times at least as early as those in which the brown bear (*Ursus Arctos*) was still living in this country, the part of the cave in which the greater part of human remains were found, viz., the "segment of depression," has come to contain those remains simply by the falling in of its roof, and of a burial-place which had existed over it whilst it was yet only an "initiatory area

of depression." We are further of opinion that at no geologically recent time previous to that of our clearing out of the cave can any very free intercommunication have existed between these two portions of it, at least at times when they were above the level of the sea; for the traces, at least those which are unmistakeable and unambiguous, of its habitation at one time by man and at another by pleistocene animals, are confined to its northern portion, which it is difficult to think they would have been if its two portions had been in open communication with each other; though the north cave is intrinsically as at present, and must have been always, better suited for the purpose in question. We have not found any evidence in this cave of man's having been a contemporary of the extinct pleistocene animals. The remains indeed of these animals themselves consist mainly of comparatively small fragments, and are representative merely of much larger quantities which were washed out of it by the sea in some later occupancies of its interior, or may have been otherwise removed.

There can be little doubt that, though man used the "north cave" for purposes of habitation, the area above the south part of it was not used except for purposes of interment. Otherwise, more relics of the articles for daily use in life would have been found in that segment. But we have no evidence to show that the first use of the "north cave" for habitation may not have been even long anterior in date to the first use of the other area for interment.

Nearly all the human bones, whether of the skull, limbs, or trunk, which were found by us in this cave, came from the previously undisturbed space in the "segment of depression;" some few, however, were found externally to the north entrance of the cave, and must, *ex hypothesi* above stated, have been passed down the whole length of the slope constituted by the "north cave." Nearly all, again, of the human skull-bones found by Mr. Edward Laws ('Journal Anth. Institute,' Aug. 1877) were lying close together, near the southern extremity of the north cave, where its upward sloping floor reaches its summit and becomes continuous with that of the "segment of depression." In other words, nearly all the human bones found in this cave were in positions into which they might, as the sections show, have been thrown or rolled if they had been lying on the roof of the "segment of depression," when that roof fell in, and, as the depth from the present natural surface round the "segment of depression" down to the red cave-earth at the bottom of it may be taken as being from 12 to 14 feet, we have here a fall sufficient to account at once for the fragmentary condition of the human and other bones found in this space, and for the space over and within which they were distributed or dispersed. *Ex hypothesi*, these bones would be showered down upon a watershed-like line of demarcation between the "north cave" and the "segment of depression," and scattered in either direction much as is the sand in an inverted hour-glass. In some cases a few bones such as the upper cervical vertebræ and some of the cranial bones would retain their natural relations of apposition, especially at the circumference under the cave walls; in others they would be widely separated; and the long bones would in almost every case be broken into longer or shorter segments. This was actually the state of the case; a state not explicable on the hypothesis of their having been introduced, as bones must so often be held to have been, by water-carriage, to say nothing of the impossibility of the feeding-ground, represented by the upper surface of the bank having been large enough to furnish sufficient water for such flotation.

We are not aware that this explanation of the presence of human bones mixed with those of domesticated animals in a cave by the gradual or sudden descent into it of such bones from a superimposed interment is necessitated by the phenomena of any other cave; it is obvious enough, however, that the concave surface presented by an "initiatory area of depression" would be very likely to suggest itself as a convenient site for such a purpose to any race of men who might be sufficiently free at once from the conventionalities of civilised life, and from the superstitions of savage life, and might be glad to take an easy way of burying their dead out of their sight. It must also be plain that no mode of burial, whether practised by civilised or by savage men, would by itself account for the scattering through so many (12–13) feet in depth of so many human bones, of so many (9–11) individuals, and this in the absence of any undisturbed burial of an entire skeleton or of a burnt body.

If the hypothesis of a number of interments having been let down into the "depression segment" will account for the presence of human bones in that portion of the Longbury Bank Cave, the great abundance of certain domesticated animals, viz., of the goat and cow, and the presence of the pig and horse, as also of edible shell-fish—limpets, oysters, and winkles—in smaller quantities, in the northern or larger portion of the cave, as also the discovery in it and upon its natural floor of the ashes of a fire-place, must be taken to prove that the main portion of the cave was used as a human habitation. Some little weight, but not very much, may also be given to the fact that of the few fragments of pottery and bone implements found inside the cave, all were found either in this part of the cave or on the surface elsewhere; and that of the worked stone implements, all but the single specimen found in the "depression segment" came also from the north cave. It would have been strange if this cave had not been employed for purposes of habitation by some one or more of the tribes of the neighbourhood, who must have become acquainted with it in some one or more of the periods in which it was, owing to one of the upheavals which have taken place along this coast, left as comparatively dry and commodious as it is at present. The easily available upward sloping entrance, admitting of refuse being got rid of without much trouble, and the height of the roof of this portion of the cave as well as the very considerable "floor space" free from stalagmitic drip which it must always since the glacial period have possessed in æras of upheaval, put this portion of the cave at great advantage for dwelling purposes as compared with the "segment of depression." And this advantage appears to have made itself evident to the pleistocene lower animals, as well as to neolithic and later man. For though some not inconsiderable amount of pleistocene remains, notably bones gnawed by hyænas, fragments of teeth of rhinoceros, and large if not always identifiable fragments from the large bones of that or other animals of similar bulk, were found in the north cave; these animals were not represented elsewhere in the cave. Further, it is highly probable that the north cave and the segment of depression may at all previous periods have been connected by but a small passage, the fragments from the roof broken off by the glacial cold or by the shocks of earthquakes having been accumulated in a great mass on the water-shed-like line of demarcation between them, and so having rendered access from the one to the other difficult. The opening of the north cave into the segment of depression is, from the top of the arch of the cave down to the natural bottom, five feet in height; and on the east side of

the opening there stands a mass of stalagmitic breccia three feet in height, and *débris* may very probably have been piled up in this place to a still higher level than this. A fissure in the junction of the two parts of the cave which still exists may have furnished an easy route for their descent. It is of importance to note that the two portions of the cave appear to have differed in function both in earlier and later times. The bones of the pleistocene animals found in this cave were limited strictly to the northern portion of it; the same may be said of the ashes, and, with the exception constituted by a single worked flint, of the implements of man's manufacture; and in this portion of the cave, whilst a very large quantity of the bones of domesticated animals was found, only a few human bones were discovered, the number of which is not greater than what the scattering northwards and downwards which the falling in of the roof of the depression segment, subsequently eked out by occasional causes such as the interference of men or of burrowing animals, foxes, rabbits, and badgers would adequately account for. On the other hand, whilst the majority of all the human bones were discovered within or immediately adjacent to the periphery of the segment of depression, the bones of domesticated animals found within it were not more in number than might be accounted for by the hypothesis of their having been the relics of funeral feasts, a view which their being intermingled with the human remains, as they would be if accumulated at successive interments, tends to confirm.

It may, indeed, be considered a matter for surprise that any pleistocene bones or teeth were left in the cave when we consider its level and the slopes of its floor; but the few that were left, and its possible exposure to the denuding influences of a pluvial period, it may be seen, might be preserved from being washed out by lodgment in the pockets and anfractuosities along the sinuous walls of the cave.

With reference to the period at which the owners of the human remains may be supposed to have lived, whether in the Stone, the Bronze, or the Iron age, the existence of the sunken forest at Westward Ho, on the opposite side of the Bristol Channel, forbids us to forget that it may have very well been some time later than the commencement of the neolithic period when the sea last encroached upon and overwhelmed areas in this district tenanted by stone-using men. And as such an invasion would have left the contents of this cave in a very different state from that in which we found them, even though no traces of metal of any kind were found inside any part of this cave, we must not suppose that we are justified in placing the date either of the men buried above or of the men who inhabited this cave far back in that period. But further. Two of the pieces of pottery found, either inside or in the *talus* just outside the north cave, appeared to be of the same style as one which was found in a round barrow, containing a cremation urn and burnt bones and flint chips, on the Ridgeway Hill, immediately above the Longbury Bank; and this may be supposed to suggest, though it by no means proves, that the Longbury Bank cave-inhabitants were, like the Ridgeway tumulus builders, of the Bronze age. • Thirdly, in the *talus* outside the north entrance, a spindle whorl made out of the bottom of a jar of Samian ware, like two found in Dowker Bottom cave, in Yorkshire (see Professor Boyd Dawkins's 'Cave Hunting,' p. 113), was found; and half of a saucer-shaped vessel of the same material showing signs of ornamentation was found on the surface of the area of depres-

sion by Mr. Laws, lying by a piece of iron slag, the only piece of metal-work found in or near this cave. Now these specimens would bring the date of the inhabitation of the cave, if they had been found *in situ* within it, down to a period as late as that in which the inhabitants had opportunities at least of procuring articles of Roman manufacture. There is other evidence to show that the date of the burials on the roof of this cave may have been no earlier than such a date; but the finding of this piece of pottery in the externally placed *talus* does not absolutely prove the date of its being inhabited to have been so. But as regards the relative age of the human interments and of the human habitation of this cave, it is of cardinal importance to note that two thin, flattish, fine-grained red fragments of apparently Romano-British pottery were found, in company with the human bones, deep down in the "depression segment." No other articles of human manufacture, however, except one worked flint, though many remains of domestic animals, were found with them. Still, it is difficult to think that these fragments were not of the same date as the human bones found with them. On the other hand, in the north cave and on the natural bottom, known locally as "Rabb," were found the ashes and fire-place already spoken of; and in the red cave-earth, just inside the mouth of the north cave and beneath the black mould, were found a flint chip, a horn-stone scraper, and a bone needle, the juxtaposition of which is not without significance.

The finding of the remains of several dogs, one old and several young ones, so closely mixed up with the human remains at the line of communication between the north cave and the segment of depression as to suggest that the two sets of remains had been buried and had fallen down together, and also the finding of a worked flint, and the absence of metal in that segment, are phenomena usual or universal in neolithic interments. But they have been all observed in interments even of the iron age.

On the other hand, the finding of the bones of the brown bear (*Ursus Arctos*) in the black mould of the north cave, and notably also in the east chamber, in company with, and similarly conditioned as to colour and preservation to, the bones of man and of domestic animals, appears to show with some probability that these latter remains should not take date later than at least the time, about 900 years back, when this bear ceased to infest Wales.

We have, then, in the stone and bone implements found in the north portions of this cave some tolerable evidence to the effect that it was inhabited by man in probably late neolithic times. And whilst the pottery found in the "depression segment," in company with the human bones, appears to show that they, or, at any rate, the immense majority of them, cannot be referred to an earlier than the Romano-British period, the remains of the bear give us a certain datum line of at least 900 years distance away from us as the latest period to which they can with any probability be referred.

We append a short summary of the results obtained from examination of all the bones obtained from this cave, whether obtained by Mr. Edward Laws or ourselves, after they had been washed, cleaned, and otherwise prepared.

Some 160 or so fragments of bones and teeth referable either to rhinoceros or elephant were found scattered throughout the northern segments of the cave. We have not been able to find that they were in positions apart from the other bones of more recent date, and usually of

different textural condition, belonging to domestic animals, to man, and to certain *feræ naturæ* still existing either in Great Britain or in Continental Europe which will be next specified. The steep slope of the part of the cave in which they were found would render the disturbance of them, and the interminglement of them with subsequent importations an easy matter, whether the disturbing agent was the sea in a period of subsidence, or rain in a pluvial period, or, finally, man himself in his successive occupations of the cave.

No remains of hyænas were found by us amongst these palæolithic bones; but the marks of gnawing, which are conspicuous enough upon many of these bones, are so closely similar to those produced by the teeth of this carnivore elsewhere, that it is difficult to think they are not to be ascribed to it; and the more so as in other caves in this district the hyæna is very abundantly represented both by bones and by *album græcum*.

Most of the bones referable to the mammoth or rhinoceros are spongy and waterworn; some combining the traces of gnawings with those of waterwear. Some, on the other hand, have received much accession to their weight and solidity, and have also become curiously polished on their exterior by exposure to calcareous drip.

In the north cave and in its eastern diverticulum the remains of bear, roe, red deer, eagle, and black grouse were found, all being animals which, without being extinct in Europe, or being foreign in strictness of language to this part of it, would yet not be very likely to find their way into this cave in the present day. Of the bear species, *Ursus Arctos*, three individuals are represented by the bones and teeth found here.

Throughout the length and breadth of the cave, from its communication with the south cave to its northern opening, and in the talus lying outside this opening, were found bones of domesticated animals, goat, small ox, dog, pig. In the talus outside the north entrance some pelvic bones were found, which I think are sheep and not goat bones. In the same locality a nearly perfect skull of a goat was found. Some of the domesticated animal bones appear to have been but of recent date, but a great number bear marks in the way of weathering and of staining of a very considerable antiquity. They represent breeds of small size.

The horse is, though but scantily, represented in the collection from Longbury Cave; and the wild boar we have failed to recognise here.

The badger's, the fox's, and the rabbit's abound among the bones collected here. The fox's represent a small variety.

As regards the human remains, the great majority of them were found in the segment of depression or in the southward termination of the north cave immediately adjoining and continuous with it. Most of the human bones found by Mr. Laws were in the latter locality; most of those found by us were found in the former; but, either by Mr. Laws, or by us, human bones or teeth were, though but in very small numbers, found in every part of the cave, not excluding even the south cave. The numbers of the several sets of fragmentary human bones may be given with some approach to accuracy as follows:—In the entire cave, exclusive of the depression segment, about 150 fragments of more or less perfect human bones were found; from the depression segment alone about 350 fragments were collected; into the talus outside the north entrance some 6 to 10 fragments of a child and of an adult had found their way; a human tooth was found in the east cave; and a piece of a skull and of a lower

jaw were found in the mouth of the south cave. These numbers of course very strongly support the view that these bones fell in from a burial place corresponding to the segment of depression; and that the accident inseparable from such a tumbling down, and the subsequent scattering inseparable from the presence of the burrowings of badgers and foxes, account for the scattering of the comparatively insignificant number of bones found at any great distance from that area. It is instructive also to put on record the fact that whilst a larger number of calvarial bones was found in the depression segment, which we suppose to have underlaid the place of interment of the human remains, than in all the rest of the entire cave, only three more or less fragmentary lower jaws were found in company with them; whilst by Mr. Laws five more or less nearly complete lower jaws were found in the north, and a large fragment of a sixth in the south cave. The palæontologist will find the frequency of the separation of the lower jaw from the rest of the cranium, with which he is so familiar, illustrated by this fact

We have absolute proof in the nine lower jaws just spoken of that no less than nine human beings have their skeletons represented in the collection made from this cave. Two fragmentary representatives of lower jaws found—one in the talus outside the north entrance, the other in the middle of the north cave—correspond probably to two other skeletons, but it is just possible that they may be parts of some one or other of the nine demonstrably distinct mandibles. Of these nine individuals, no less than five were males in or beyond the middle period of life, one belonged to a woman in late life, one to a person about the age of puberty, with the wisdom tooth as yet uncut, one to a child with the first two molars just cut, one to a child with none but the milk teeth in place.

Three more or less perfect calvaria have been reconstructed out of the remains collected by Mr. Laws and ourselves; one from the cranial bones found in the north cave, two from those found in the depression segment. All of the crania are dolichocephalic; and one, a male skull, that which came from the north cave, "mecistocephalic," in Professor Huxley's language, with a cephalic index of 69, and with the pear-shaped contour when viewed from above, due to rapid tapering from the level of the parietal tubera forwards, which has so often been spoken of since the writings of Professor Daniel Wilson as characteristic of many skulls from the earliest sepultures of Great Britain. There is no doubt that this is a very ancient form of skull, but the well-known tenacity and persistence of such ancient forms forbids us to use it as an evidence as to date. Of the other two, one belonged undoubtedly to a man, the other to a woman; and neither, though dolichocephalic, are exaggeratedly so, as is the case with the first-named of the three.

The long bones are all more or less fragmentary; they do not present any peculiarities specially worthy of notice; the femora have not their *lineæ asperæ* greatly developed, though in one or two the upper portion of the shaft is somewhat flattened from before backwards in the origin of the insertion of the glutæus maximus; the tibiæ are not platycnemic; and neither these nor any other of the bones give the notion of their owners being much above or below the average size and height. In a word, they have not the peculiarities of prehistoric bones. The human bones present much the same appearance as to staining, wear and tear, and weathering as the bones of bear and of domesticated animals found with

them. All three sets of bones alike differ from those belonging to the palæolithic period found here in being, except in a few instances, free from interstitial calcareous deposit, and from marks of gnawing except by recent rodents.

In one instance, some human bones were found imbedded in reddish-white breccia. This breccia had been formed in several places along the east wall of the north into masses about 3 feet to 3½ feet in height, which stood out against the wall like brackets. One of these, just 15 feet from the north entrance, had embedded on its upper surface, which was about 3 feet 10 inches above the natural floor of the cave, the lower ends of two human femora, which thus came to occupy just such a position as they would be likely to do if picked up from the floor by some human inhabitant who was incommoded by their presence and placed on the top of the shelf-like bracket which was in the process of being added to by drip. With these two human bones are concreted some bones of frogs or toads, and at a depth of one foot a humerus of a roe, *Cervus capreolus*, was found similarly embedded. It is of importance to note that these brackets of breccia do not seem to be remnants of a floor which has disappeared from between the side-walls of the cave; no corresponding deposits at least are observable along the opposite wall on the west side, and, as is well known, the stalagmite-forming drip, being regulated by the conformation of the limestone, is very often anything but symmetrically arranged.

Report of the Committee, consisting of Professor Sir WILLIAM THOMSON, Mr. W. FROUDE, Professor OSBORNE REYNOLDS, Captain DOUGLAS GALTON, *and* Mr. JAMES N. SHOOLBRED (*Secretary*), *appointed for the purpose of obtaining information respecting the Phenomena of the Stationary Tides in the English Channel and in the North Sea; and of representing to the Government of Portugal and the Governor of Madeira, that, in the opinion of the British Association, Tidal Observations at Madeira or other islands in the North Atlantic Ocean would be very valuable, with the view to the advancement of our knowledge of the tides in the Atlantic Ocean.*

THE Committee beg to report that last year the French Association for the Advancement of Science, at their Meeting at Havre, which took place subsequently to that at Plymouth, having had the subject of these simultaneous tidal observations in the English Channel and in the North Sea brought before them by the Secretary of the Committee, cordially approved of the intended action of this Committee, and resolved to urge upon the French Government that any observations required upon the French coast should be undertaken by its engineers.

At the commencement of the present year, the French Government undertook to do this, in accordance with a programme of simultaneous observations, approved of by the Chairman of the Committee.

The Belgian Government likewise offered its co-operation at Ostend; and in Holland the observations were kindly undertaken by the authorities

at the mouth of the North Sea Canal and at Flushing; while on this side of the Channel, extending from Portland to Yarmouth, the port and other authorities at the points selected also undertook the duties of making the necessary observations.

The results have not yet been all received, and they are not in a sufficiently forward state to be presented at this meeting.

In consequence of the great importance of accurate permanent tidal records at Dover being available, the Chairman of the Committee urged upon the Warden of the Cinque Ports, Lord Granville, that a self-registering tide gauge should be erected at Dover; a proposal which met with his Lordship's cordial approval and support.

The Board of Trade have further consented to grant a suitable site for the erection of a self-registering gauge on the Admiralty Pier, and have undertaken to defray the cost thereof.

The exact form best adapted to the place is at present under consideration, but it is confidently hoped that before long a self-registering tide gauge will be permanently at work at this very important locality.

The subject of tidal observations at Madeira was brought under the notice of H.M. Government by the Chairman of the Committee.

A communication has lately been received from the Foreign Office, saying that H.M. Minister at Lisbon, having urged the matter upon the Portuguese Government, "has received the assurance that it will gladly adopt the suggestion of the British Association and establish a tidal gauge at Funchal."

In consequence of the results of the tidal observations already undertaken not being in a sufficiently advanced state for presentation at this meeting, the Committee request to be reappointed, and also that £10 be placed at their disposal.

Appendix.

Board of Trade, (Harbour Department),
Whitehall Gardens, S.W., July 11th, 1878.

SIR,—With reference to a letter, dated the 31st May last, addressed to this department by Sir William Thomson, LL.D., in his capacity of Chairman of the Committee of the British Association, "on Tidal Observations in the English Channel, &c.," calling attention to the want of a tide gauge at Dover, and enquiring whether the Board of Trade would be disposed to undertake the expense of placing a continuous self-recording instrument at the Government pier, where there is already a tide-well, I am directed to acquaint you that this Board have received the sanction of the Lords Commissioners of Her Majesty's Treasury to the expenditure for this purpose of a sum not exceeding one hundred and five pounds (£105) (the estimated cost as given by Sir W. Thomson), and I am to state that your Committee are at liberty to take the necessary steps for fixing the gauge.

I am to add that Mr. Druce, the Resident Engineer and Officer of this Board at Dover, has been instructed to give such facilities in the matter as he is able to afford.

I am, Sir,
Your obedient servant,
C. CECIL TREVOR.

J. N. Shoolbred, Esq.,
3 Westminster Chambers, S.W.

Foreign Office, August 9th, 1878.

SIR,—With reference to my letter of the 7th inst., I am directed by the Marquis of Salisbury to transmit to you herewith a copy of a telegram which has been received from Her Majesty's Minister at Lisbon on the subject of the establishment of a tidal gauge at Funchal.

I am, Sir,
Your most obedient, humble servant,
JULIAN PAUNCEFOTE.

J. N. Shoolbred, Esq.,
3 Westminster Chambers.

(*Mr. Morier to Lord Salisbury.*)

Lisbon, August 9th, 1878, 1.18 p.m.

I have received the assurance that the Portuguese Government will gladly adopt the suggestion of the British Association and establish a tidal gauge at Funchal. The official note on the subject cannot be sent for some days, as Senhor Corro is absent.

Second Report of the Committee, consisting of Professor Sir WILLIAM THOMPSON, Major-General STRACHEY, Captain DOUGLAS GALTON, Mr. G. F. DEACON, Mr. ROGERS FIELD, Mr. E. ROBERTS, *and* Mr. J. N. SHOOLBRED (*Secretary*), *appointed for the purpose of considering the Datum-level of the Ordnance Survey of Great Britain, with a view to its establishment on a surer foundation than hitherto, and for the tabulation and comparison of other Datum-marks.*

THE Committee, in their Report of last year, dealt with the question of some uncertainties which existed as to the position of the Ordnance datum-level, and of its relative position to other local datum-marks in Liverpool. On the present occasion the Committee beg to report that a list of local datum-marks, and the connexion of each with the Ordnance datum, is in course of preparation. They beg to be reappointed, with the grant of £10 (not drawn) to enable them to complete the list of local datum-marks.

Report of the Committee on Instruments for Measuring the Speed of Ships, consisting of Mr. W. FROUDE, Mr. F. J. BRAMWELL, Mr. A. E. FLETCHER, Rev. E. L. BERTHON, Mr. JAMES R. NAPIER, Mr. C. W. MERRIFIELD, Dr. C. W. SIEMENS, Mr. H. M. BRUNEL, Mr. J. N. SHOOLBRED (*Secretary*), Professor JAMES THOMSON, *and* Professor Sir WILLIAM THOMSON.

THE Committee regret to say, that the Chairman has been unable to complete the second series of experiments with the several instruments for measuring the speed of ships.

The Committee therefore beg to be reappointed, and that the grant of £50 (which has not been drawn) be renewed.

Report of a Committee appointed for the purpose of further developing the investigations into a Common Measure of Value in Direct Taxation, the Committee consisting of the Right Hon. J. G. HUBBARD, *M.P.*, Mr. CHADWICK, *M.P.*, Mr. MORLEY, *M.P.*, Dr. FARR, Sir GEORGE CAMPBELL, *M.P.*, Mr. HALLETT, Prof. JEVONS, Mr. NEWMARCH, Mr. SHAEN, Mr. MACNEEL CAIRD, Mr. STEPHEN BOURNE, Prof. LEONE LEVI, Mr. HEYWOOD, *and* Mr. HALLETT (*Sec.*)

I. YOUR Committee presented to the British Association a first Report of the results of their inquiry on this subject in 1876. In this inquiry, following ordinary usage, they took income as the basis of their examination. They found, however, that in sundry proposed systems of common valuation and assessment on this basis, incomes were sometimes considered in themselves independently, sometimes in relation also to their owners. The first consideration was directed to the real nature and constitution of income, as the annual value, product, profits, or receipts of, or from, some given source, whether land, labour, or capital. The other consideration was directed to the income's relation to personal circumstances, or in other words, to the owner's position in the scale of riches and poverty as determined by his possession. Assessment on the former principle would vary with the positive value of the income, on the latter it would vary with the value of the income qualified by the individual condition of the owner—his individual tenure for example or his individual necessities. £1,000 a year from land held on a short tenure or subject to large family claims, would on the latter view be differently assessable to the same income held on a long tenure or not subject to these claims, whilst on the former and sounder view the two assessments would be the same. The Committee in dealing with the subject referred to them, confine their attention to the income's positive value. Positive value is the professed basis of the present Income Tax, and were it possible to adjust an Income Tax to differences of individual tenure and necessities, as well as to differences of positive value, some uniform method of comparing and measuring the positive values of incomes would still be essential. It is impossible to estimate the relative effect of incomes upon different individuals without first knowing their values considered in themselves.

II. But the equal assessment of incomes according to positive value demands a common measure of value, and legislation, in the absence of such common measure, must act on a mere nominal equality which often involves it in a real and gross injustice. £1,000 a year from perishing labour,—that for instance of a barrister or physician,—is taxed equally with £1,000 a year from permanent land. The question then presented itself, " how does the difference between nominal equality and true equality, or as it might be called, the difference between nominal income and true income arise, and how is it expressible? " The Committee considered that this difference was universally resolvable into the extent to which the production of an income involved the expenditure of its source's value. Labour, land, houses, and other great sources of income, are more or less consumed, impaired, or diminished—some more, some less,—in producing income, and this varying diminution in the source's value appears as a more or less enlarged income and makes it of more or less nominal worth. Such nominal income is in fact a mere mixture of true

income and source's outgoings, and the more the source is impaired in value, the larger is the proportion of these outgoings in its composition, whilst the greater also will be its nominal excess above true income. From these considerations the Committee arrived at the following simple rule of general application:—"Deduct from the income as at present returned the outgoings that belong to its production, and the remainder will be its taxable amount."

III. Under such a rule, taxable income would not as at present be land-rent, house-rent, labour-wages, &c., but land-rent *minus* land-outgoings, house-rent *minus* house-outgoings, labour-wages *minus* labour-outgoings, &c. These outgoings are for the most part the sequels of productive wear, tear, and depreciation, involving cost of repairs, maintenance, or replacement either of the source itself or of its value. By their deduction the source's value considered as a capital or principal, is maintained unimpaired, and the income left which would always bear the same relation to source that interest bears to principal, was called the source's "interest value," and was adopted as the common measure of assessment. The plan of the Committee might indeed be shortly summed up as the conversion of sources and incomes generally to the form of principal and interest by uniform deduction of source's outgoings, and might be indifferently defined as, "Taxation of the Interest value," "Non-taxation of the Principal value as Income," "Exemption of Essential Outgoings," three equivalent expressions, each one absolutely involving the other.

IV. Incomes in their positive or source aspect as the object of direct assessment and interest value as the assessment's common measure—such are then the chief conclusions of the last Report. In the present inquiry, keeping this object and this measure distinctly in mind, and keeping clear of all purely personal aspects, whether those of personal tenure or of personal necessities, the Committee propose to determine more fully the method and practicability of applying this measure to the chief cases of actual Income and to append an approximate schedule of results.

V. The rule of procedure in general is evidently that already given for finding interest value, viz., "Deduct from the income as at present returned all the outgoings that belong to its production," or speaking independently of the Income Tax and its returns: "Deduct from the total receipts of any given source, the total cost of producing them, and the difference will be its interest value on taxable income." This being the rule, all that will be necessary for its particular application will be a knowledge of the receipts, and a knowledge of the outgoings or costs in each case in question. What are the costs to which land, houses, and mines are naturally subject in producing rents and royalties? What are the costs to which ships, machinery, horses, cattle, vehicles, trade fixtures and furniture, railways, mills, and manufactories, in a word capital whether fixed or circulating, are subject in producing profits? What are the costs to which labour, whether of offices, of professions, or of trades is subject in producing salaries, fees, or wages? These costs consist as before stated of the source's outgoings through work, wear, and tear, and through depreciation in value by age and exhaustibility, and equally with that of the source's receipts a knowledge of them is implied in every comparison of values and is indeed the indispensable condition of all rational accounts.

VI. Fortunately, however, the practicability of finding and deducting

these outgoings, or costs, does not merely rest on the reason of the thing, but in many cases is proved by actual precedent. The Income Tax Act itself allows them in some cases, though it ignores them in others, both recognition and non-recognition being equally haphazard and arbitrary. It was recently stated by the Chancellor of the Exchequer, that deduction for depreciation in ships and railways, though not expressly recognised in law, were practically recognised in the assessment offices. Depreciation in machinery is now added by special enactment, whilst the Law Courts have recently discovered that allowance for depreciation in mines has always been the real though the hitherto hidden meaning of the Act itself. Special clauses of the Act expressly allow cost of repairs and renewals. The immemorial usage of calculating the profits of capital in business, viz., that of valuation of stock at the beginning and end of the business year, and the inclusion of the difference in the profit and loss account, involves a distinct deduction of source's outgoings, and the Act in so far as it recognises this usage, recognises and allows this deduction. Moreover in other instances to which the Act is partially or wholly blind, precedents of practicability are not wanting. Deductions from gross annual value, in order to obtain rateable value, have ever been recognised in local taxation, though in the absence of a common measure of value, in a variable and uncertain manner. The Metropolis Valuation Act of 1869, "an Act to provide for uniformity in the assessment of rateable property in the Metropolis," and the various Valuation Bills proceeding from it, are founded upon these deductions, to which they attempt to give a uniform and common basis, and their appended schedules, if not wholly accurate, are valuable precedents for direct taxation generally. In these, lands without buildings are allowed a deduction of $\frac{1}{20}$; with buildings not houses of $\frac{1}{10}$; houses are allowed a deduction varying according to their class from $\frac{1}{4}$ to $\frac{1}{6}$, mills and manufactories a deduction of $\frac{1}{3}$, &c.: all these deductions representing the expenses to which the several properties are liable, as necessary to "maintain the hereditament in a state to command its rent."

VII. In the case of labour, however, no deductions are allowed either in practice or in legislation, and yet the income from the labour of men is as subject to essential outgoings, costs of maintenance, depreciation, exhaustibility, as the income from houses or from horses. A man's labour, it is popularly said, is his capital, but if so, it is both a consumable and perishable capital. Like the labour of a horse, to take the previous example, it undergoes a daily exhaustion of power that has to be supplied by food. As the horse has to be clothed and stabled, so the productive labourer has to be clothed and housed. As the horse by age undergoes a depreciation of its value, so by age the productive labourer undergoes a similar depreciation, and as the work and value of the horse finally disappears, so does the labour and value of the labourer disappear also. As questions of economic valuation, the cases of the working horse and working man, be his work mental or manual, are precisely analogous, and the outgoings of the labour's value that are capable of calculation and allowance in one case, are capable of calculation and allowance in the other. The calculation in the case of horses, is the necessary condition of maintaining a business in horses. A job-master, for example, may receive from the hire of a pair of horses worth £200, which he supplies with food, stabling, and attendance, full £200 a year. The Income Tax assessment even, would scarcely venture to charge such

a capitalist with an income of £200 a year for each pair of horses thus let; he would be allowed a deduction for the food, stabling, and hired attendance. But the horses in the course of half a dozen years are worn out, and have to be replaced, and he is allowed a deduction for this expense also, if not in the shape of a fund annually put by for depreciation, at any rate in the shape of cost for resupply of diminished stock. The Income Tax assessment, however, does charge in this manner the labour of the capitalist himself, and thus not only is the man of industry assessed on powers in his possession on which the man of idleness is not assessed at all, but he is assessed on the gross receipts of these powers, whilst their necessary expenditure, with the exception of the small insurance allowance, is absolutely ignored.

VIII. As an individual's labour is thus a possession of limited and uncertain duration, and subject to an annual expenditure for maintenance, the true mode of valuing its income would be to regard it as a terminable annuity, subject to an annual cost. In this aspect the amount of this annuity would be that of the labour income at present returned, its term the average labour period, and the annual cost that of the labour's maintenance. This annual cost, which would in general be expressible as some proportion or percentage of the income, added to the annual fund necessary to replace the capital of the annuity, would be the deduction required for finding the labour's interest value, or taxable income. With the requisite statistics, the calculation of this deduction is a question of arithmetic. By a witness in the Hume Committee, it was stated as $\frac{1}{2}$ of the present assessable labour income, just as the deduction in mills and manufactories is given as $\frac{1}{3}$, and that of certain classes of houses as $\frac{1}{4}$ of their respective rents, and this, if not the exact truth, must be a close approximation to it. A summary of these deductions is presented in the following schedule, and the general adoption of the single principle they illustrate would secure the immense advantage of a uniform plan of assessment throughout both local and imperial direct taxation.

Schedule of an Assessment of Incomes according to their Interest-value, the Principal-value of each Source being maintained by deduction of all Essential Outgoings.

SOURCES OF INCOME.

PROPERTY.

	Deduction per cent. or proportion
1. Land, according to presence or absence of buildings	From 5 to 10 or $\frac{1}{20}$ to $\frac{1}{10}$
2. Houses and buildings, according to class	From $16\frac{2}{3}$ to 25 or $\frac{1}{6}$ to $\frac{1}{4}$
3. Mines and quarries, according to class	From 10 to 20 or $\frac{1}{10}$ to $\frac{1}{5}$
4. Mills and manufactories, including blast and smelting furnaces and kilns	$33\frac{1}{3}$ or $\frac{1}{3}$
5. Moneys invested in Exchequer Bills and Bonds, Perpetual Annuities, or Loans	Nil
6. Moneys invested in Terminable Annuities	Sufficient to restore capital
7. Railways, Canals, Docks, Tolls, Waterworks, and Gasworks	To be determined in each case according to the ordinary rules of valuation for stock taking and balance sheets.
8. Ships, vehicles, machinery, trade fixtures, horses, stock, and other forms of capital, whether fixed or circulating	

LABOUR.

9. "Professions, Trades, and Offices," including salaried, agricultural, manufacturing, and commercial employments .... 50 or ½

IX. Where the nominal or gross income is the joint result of property and personal labour, as in all trades, and in many professions, we have first to consider the property income and labour income separately. If the property be valued by the foregoing rules as a principal or capital, it is a truism to say that the interest of the principal will be the interest-value of the property, and that this subtracted from the joint income will give the labour's nominal income. Deducting the labour's outgoings from the latter, we have the labour's interest-value, which added to the property's interest-value, makes the total assessable return required. Examples of the rule are given in the first Report. Being merely a rule of valuation it is as legitimately capable of application by the owner of a business, or by his recognised accountant, as any of the rules now in use, and being thus applied it involves no exposure of his capital or other detail of his business. The following are forms of ordinary account, illustrative of the application of the rule to particular cases.

LAND WITHOUT BUILDINGS.

Cr.	£	Dr.	£
Nominal or gross rent	1000	Deduction for land-outgoings at $\frac{1}{20}$	50
		Land interest-value or taxable income	950
	£1000		£1000

HOUSES BETWEEN £20 AND £40 OF GROSS ANNUAL VALUE.

Cr.	£	Dr.	£
Nominal or gross rent	1000	Deduction for house-outgoings at	200
		House interest-value or taxable income	800
	£1000		£1000

LABOUR.

Cr.	£	Dr.	£
Nominal or gross labour income ...	1000	Deduction for labour-outgoings at ½................................	500
		Labour's interest-value or taxable income	500
	£1000		£1000

LABOUR AND PROPERTY COMBINED IN BUSINESS.

Cr.	£	Dr.	£
Nominal income from business of £1000 consisting of:—		Deduction for labour-outgoings at ½..............................	300
1. Interest of £10,000 of capital, say at 4 per cent	400	Business' interest-value or taxable income	700
2. Nominal labour-income...........	600		
	£1000		£1000

X. To the question of the mode and practicability of applying the common measure of interest-value to cases of property and labour income, the above is perhaps a sufficiently detailed answer. In all these cases the measure is applied to the positive, or source aspect of the income, and not to the personal. In all, the deductions are intended to represent the source's average essential outgoings. In all, the interest-value is the excess of receipts over these outgoings, or the principal-value of each source is, by means of the deduction, maintained unimpaired, and hence in a condition to command its future income. The Dr. and Cr. forms appended are exemplars of the modes of making the deductions. They show that the process of making them is merely that of keeping a strictly uniform and just system of accounts, and that any system of accounts that omits them is neither uniform nor just. Moreover, the balance of each account exhibiting the true taxable income, is that alone needful for the return. It is not affirmed that the amount of deduction given in each case is exact, but exactitude—at least insurable exactitude—is purely a question of fact. From the facts obtained in a Government office, for example, it might appear that as in the case of houses the proportion of outgoings diminishes as the receipts increase, so would they also in the case of labour. But if so the remedy already applied to one in local assessment would be the remedy for both in imperial assessment, viz., a scale of outgoings relative to such increase of receipts.

Comparison of the Measures of Interest-value and Capital-value.

XI. Such is the system of assessment which your Committee recommend for adoption. In discussions however on the question of direct assessment, another common measure has often been proposed. It has been proposed to assess incomes, not according to their real annual or interest value, but according to their total or capital value, or in other words according to the present money value to which they are equivalent, and from which they might be supposed to be derived. Valuation by capital value, capitalisation as it is called, finds a common measure and expression in the numbers defining what is called the years' purchase of the income. Thus an income valued at 25 years' purchase, *cæteris paribus*, is worth twice as much as one valued at $12\frac{1}{2}$ years' purchase, and in the system of capital-value would be taxed twice as much. The figure defining the years' purchase of an income, is thus at once an index or measure of an income's value and of its assessability. As this system is a simple, popular, and well understood mode of valuation, it will be useful to consider and compare the results it gives with those of interest-value, and this comparison can be made by means of the annexed table (p. 226). The first column expresses the series of incomes equal in present value, but varying in annual amount, from £4 per cent. up to £20, a variation that might evidently be extended either way, and this column alone is sufficient to show the lack of consciousness, if not of conscience, in taxing incomes according to abstract annual amount. The second column expresses the capital value of each of these incomes in years' purchase of its annual amount. Under the supposition of a £4 per cent. normal rate of interest, the third column shows the percentage amount of source's outgoings in, and of the consequent deduction from each income, and the fourth shows the percentage amount of interest-value in each. A com-

A series of Nominal Incomes of the same real present worth, with their comparative estimation by the two measures of Years' purchase and Interest-value. Each income is formed at the same rate, viz., £4 per cent. of real profit, every apparent excess representing the amount of undeducted outgoings that the income exhibiting it contains.

Nominal Incomes from £100	Their Capital-value in years' purchase of their amounts	Their Outgoings in percentage of their amounts	Their Interest-value in percentage of their amounts
£4	25	0 per cent.	100 per cent.
5	20	20 " "	80 " "
6	16·6	33 " "	66 " "
7	14 3	43 " "	57 " "
8	12 5	50 " "	50 " "
10	10	60 " "	40 " "
15	6·6	72 " "	27 " "
20	5	80 " "	20 " "
etc.	etc.	etc.	etc.

parison of the figures of the second and fourth columns, representing the respective valuations of the same series of incomes by the two measured shows that these valuations are in exact proportion, and shows therefore that at a given rate per cent., the taxation of an income on its interest-value is the same as its taxation on the number of years' purchase expressing its capital-value. Thus for example in the above table an income of 4 per cent. is worth 25 years' purchase, and all of it, or 100 per cent., is true interest-value. An income of 8 per cent. is worth 12·5 years' purchase, and its interest-value is only 50 per cent. of its amount, the other 50 per cent. being outgoings of principal. The figures expressing the number of years' purchase of the two incomes, viz., 25 12·5, and the figures expressing their interest-value, viz., 100 and 50, are proportionals. So with any other corresponding numbers of the two columns, and generally the two lines of figures, while proportional to each other, have a measurable relation to the line of figures expressing the outgoings. These relations, which strictly follow from the nature of capital and interest, or principal and interest, are important, because though, for reasons stated in the first Report, an interest-value measure as representing the annual increment or actual increase of value, is a better measure of annual taxation than that of capital, yet a knowledge of the capital-value of an income is often a rapid and useful mode of getting at its interest-value. By means of such a table as is here shown, the value in years' purchase of any income from property or labour being given, the amount of outgoings to be deducted in order to maintain the source's principal unimpaired, or the amount of the interest-value, can be at once exhibited. As an outcome of this comparison it may be said that to the three equivalent sides or illustrations of the assessment doctrine of incomes already given, viz., "Taxation of Interest-value," "Non-taxation of Principal as Income," "Exemption of Essential Outgoings," we may add what is practically a fourth, viz., "Taxation according to their Years' Purchase," always provided that a uniformity of basis and application be preserved.

XII. It appears to be sometimes thought that the capitalisation of incomes is equivalent to the conversion of an Income Tax into a Property Tax. This however is not so. An Income Tax, whatever the measure used, always demands an income. A Property Tax, however, would take effect if there were no income. It is indeed the necessary condition of property, having value, to produce income sooner or later, and equal properties in the long run produce equal incomes; but the advantage of an Income Tax over a Property Tax, is that it falls on the property only when it does produce an income, and in proportion to the amount produced. One of the advantages of a Property Tax over an Income Tax is said to be that of its incidence on certain forms of value not reached by the Income Tax, as for example, lands annually increasing in value in the neighbourhood of growing towns, but yielding no corresponding rent, and also the furniture, &c., of private houses. If true income be increment or increase of value it may be fairly questioned whether the annual increase of value in these lands is not true income, and truly liable to Income Tax. Under the present system, a capital invested in such property year by year increases in value, but pays no Income Tax on the increase, whilst the same capital invested in funds or farms would be annually assessed on its increase. It may be also questioned whether property in furniture, rightly considered, is not as much property yielding an income to its owner as the house which he owns and at the same time inhabits. It has an annual utility, and its value invested in other forms would yield income. Moreover, in this same form, if hired instead of owned, it yields an annual income annually taxable, and it is difficult to see how the fact of the same property being owned by one and used by another, and being owned and used by the same person, can make a difference in the nature of its annual use, value, or product. Questions of this kind, however, belong rather to the province and extension of a direct tax than to its just valuation.

XIII. Many of the objections which have been urged against capital-value are probably grounded, not so much on a repugnance to the measure itself, as to the mode in which it has been used, as for example, in reference to the subject of tenures pointed out in the last Report. Uniformity of basis and application, whatever the measure may be, is of the last importance, and the confusion that may attend the use of a true measure was well exemplified in the arguments on the Knowles case, a colliery Income Tax appeal, recently decided in the Court of Exchequer. In this important case for Income Tax reform, the plaintiffs, maintaining the principle that real income or profit is the difference between expenditure and receipts, claimed at law a deduction from the taxable receipts of coal mines for the exhaustion of the coal. Among the replies made by the Inland Revenue Office as defendants, was "that if real income be the difference between expenditure and receipts, why should not a person who buys a lease in lands or consols be assessed to the Income Tax on the difference between what he gives for his lease and what he receives from it"—a difference that would practically amount not to the interest-value of the consols or land, but to the interest-value of his purchase money. The answer is, "real income is the difference between expenditure and receipts, but the analogy of a lease is a fallacious one. In expending money on a lease, you are not, as such, producing an income, nor are you buying that which produces it; you are simply buying incomes already made or to be made independently of your purchase. You are in fact a

dealer in incomes, just as you might be a dealer in sugars or teas, or in any other commodity, taxable antecedently to your purchase, and you buy them subject to all their burdens. Your receipts are in this case themselves incomes, themselves the difference between expenditure and product, and the tax on them, though charged to the full amount, is a charge on the money that buys them only in the same manner that the tithe is a charge on the purchase money of lands."

The fallacy of refusing a deduction to the products of perishable sources, and the fallacy of claiming a deduction for the terminable tenure of permanent products, are the obverse forms of a financial illusion. Both fallacies arise from the phenomena of transfer. In the former, true capital by transfer appears as income, and is taxed as income; in the latter, true income by transfer appears as capital, and as capital would be exempted. It is this double illusion, ever manifesting itself in investigations on the Income Tax, that has probably confused the vision of economists and statesmen, and hitherto rendered abortive all attempts at reform. Whether direct taxation be incident on property or on its products—on capital or on income—for a series of years matters little; but it is monstrous that a tax which professes to be either a Property or an Income Tax, should treat capital as if it were income, or income as if it were capital.

XIV. It sometimes appears to be thought that after all there is little practical difference whether taxation be levied on gross income or on net, on the higher or lower level as it is called. "A certain sum has to be raised, and what matters it whether it be raised as a smaller percentage of a larger sum or as a larger percentage of a smaller one." Doubtless if gross income bore the same relation to net in each case such an argument would be valid, but no such relation exists. The "grossness" of an income stands for the amount of undeducted expenditure the income contains, and gross incomes are of every degree of "grossness." The true net pound—the interest-value pound—is in all cases 20*s.*, but the gross pound is as variable as the nature of sources and the customs of free contract. In land rent the gross pound is legally defined in the Metropolis Valuation Act as 19*s.*, in house rent as varying according to the class of house from 15*s.* to 17*s.* 8*d.*, in the rent of mills and manufactories as 13*s.* 4*d.*, in the wages of labour, though not yet legally defined, it is probably only 10*s.* All however are pounds gross, and in an assessment proportioned to gross value like that of the existing Income Tax, are equally assessable. By this mode of reckoning, an Income Tax nominally 5*d.* in the pound, is indeed for ordinary principal moneys really 5*d.*, but for houses it is in some cases between 6*d.* and 7*d.*, for mills and manufactories it is 7½*d.*, and for labour it probably amounts to 10*d.* Gross value is thus not a single measure, but is a loose expression including a number of measures, it may be a multitude of measures, presenting a conspicuous absence of uniformity of relation both to true value, and to each other. Perhaps the one positive point of community these measurements by "gross" value do possess is their inordinate pressure on labour and the products of labour as compared with their pressure on the permanent sources of income. Human labour and the works of human labour have as their distinguishing marks waste and perishability. They essentially constitute the great category of things, *quæ ipso usu consumuntur*, but it is "consumability by use" that "gross" value utterly ignores. Between the permanent and the perishable it distinguishes

nothing, and human labour in itself, and in its works, in its houses, its mills, its manufactories, are the special victims of this ignorance.

XV. To contemplate modes of valuation such as these now employed, as not the mere dicta of individual opinion, but as the accepted conclusions of the State and the expression of its established law, would be to despair of truth and justice in direct taxation. If, however, instead of confining our attention to the present position of the valuation question, we regard it in its successive changes and in relation to the progress in the branch of science of which it is a part, reason for hope will appear. Measures of value, like other measures, have their movement. The history of measurement in general is in a high degree the history of exact science, and whether the subject matter be lines or angles, forces or values, this history presents an early state of "grossness" and disorder that only by the slow march of intelligence developes into definiteness and uniformity. And the history of the measurement of values in particular, low down in the scale of accuracy as it now is, yet presents an undoubted ascent from a still lower condition. Sceptics indeed, both without, and also, we regret to add, within the limits of this "Association for the Advancement of Science," have doubted the possibility of a science of values—of the science, that is to say, which forms the peculiar charge of this Section—but the ebb of doubt has ever attended the wave of progress, and the best antidote to such doubt, as well as the best stimulus to further progress, is the consideration of the onward course of statistical facts themselves. In the particular subject under discussion, the two great parliamentary commissions of 1851–52 and of 1860, in which many of the leading members of this Economic Section took a leading part, evidenced the awakening of the public mind to the necessity of a change. The Union Assessment Act of 1862; the Metropolis Valuation Act of 1869; the Local Valuation Bills grounded on these Acts annually introduced into Parliament; the recent decision of the Court of Exchequer in the appeal case of Knowles *v.* McAdam; the deduction allowed in this year's Inland Revenue Bill for depreciation of machinery, are all incidents of a progress towards a better measurement of values; and in these incidents collectively considered, your Committee recognise a system of lines of reform converging to the principle which they have attempted in their Reports to define and illustrate. It need scarcely be added, that the indirect results of true valuation, for example, its effect on the truth of returns, are not less important than those which are direct. A false system of valuation must of necessity encourage false returns. To deceive or to be plundered are its only alternatives, nor is it wonderful that popular casuistry often prefers the former. A true method of valuation on the other hand encourages true returns; it may not absolutely secure them, but it secures the removal of all that can obstruct them, and cancels the invitation to fraud, afforded by the present law. A true valuation alone can justify the exact and vigorous administration which must be the characteristic of an equitable tax on income.

Report on Sunspots and Rainfall. By CHARLES MELDRUM, *F.R.S.*

[A communication ordered by the Council to be printed *in extenso* among the Reports.]

1. In 1873 and 1874 (see British Association Reports for those years) I submitted tables of the rainfalls of various parts of the world, and expressed the opinion that there was strong evidence of a connection between rainfall and sunspots.

2. Having received additional observations, I now beg to submit the principal results obtained by comparing the rainfalls of different countries, and the levels of some of the rivers of Central Europe with Wolf's relative sunspot numbers.

3. Probably the best method of comparing the sunspots with the rainfall is that of the harmonical analysis. In a paper which was communicated to the Royal Society in January, 1876, I applied that method to the annual mean rainfalls of the greatest possible number of stations scattered over the globe, and to the mean annual depths of some of the rivers of Central Europe, and found not only that there was a rainfall cycle of nearly the same length as the sunspot cycle, but also that the two cycles had the same characteristics with respect to the intervals between the epochs of minimum and maximum and maximum and minimum, a circumstance which strongly pointed to a causal connection. But, as the method is laborious, I have not yet had time to apply it to the rainfalls of single stations, or even to the mean rainfalls of different countries. I hope to be able to do so soon, and to communicate the results on another occasion.

4. In the meantime the probability or otherwise of a connection between sunspots and rainfall may be shown by the old method of arithmetical means.

5. Although the mean length of the sunspot cycle is about eleven years, yet, in employing the method of arithmetical means, it would be objectionable to commence with any year whatever in a long series of observations, and taking the greatest possible number of periods of eleven years each, compare the annual mean rainfalls with the annual mean sunspots; for by doing so the maximum and minimum years might be so much dispersed over the common eleven-year period thus formed as to conceal any periodic variation that might exist. It is essential to refer the comparisons to the epochs of maximum and minimum, and this cannot well be done by commencing with any year whatever.

6. With a view of avoiding that objection as far as possible, and at the same time of obtaining a simpler and more expeditious method than that of the harmonical analysis, I make two comparisons, in one of which the maximum years of sunspots are taken for the point of reference, and in the other the minimum years.

7. As the epoch of maximum sunspots occurs on an average 3·7 years after the epoch of minimum, and the epoch of minimum 7·4 years after the epoch of maximum, the maximum years in the first comparison are all placed in the *sixth* of thirteen terms or series of years, while in the second comparison all the minimum years are placed in the *eighth* or *ninth* of other thirteen terms or series. Then, with the object of diminishing the effects of so-called accidental irregularities in the rainfall, the

hirteen terms are reduced to *eleven*, and these, for convenience, are called the 'mean cycle.'

I.—Sunspots.

8. Applied to Wolf's relative numbers of sunspots (latest edition), the above method gives the following results for the years 1811–77 :—

TABLE 1.—Sunspot numbers.—Maximum years in 6th line.

Years	1811–23	1824–36	1832–44	1843–55	1855–67	1865–77	Means	Mean Cycle	Variation	Years of Cycle
1	1·6	8·1	26·3	*13·1	7·7	31·4	14·7	—	—	—
2	4·9	16·2	*9·4	19·3	*5·1	14·7	11·6	14·9	−33·9	1
3	12·6	35·0	13·3	38·3	22·9	*8·8	21·8	25·4	−23·4	2
4	16·2	51·2	59·0	59·6	56·2	36·8	46·5	48·8	0·0	3
5	35·2	62·1	119·3	97·4	90·3	78·6	80·5	77·0	+28·2	4
6	**46·9**	**67·2**	**136·3**	**124·9**	**94·8**	**131·8**	**100·4**	**91·9**	**+43·1**	**5**
7	39·9	67·0	104·1	95·4	77·7	113·8	83·0·	83·0	+34·2	6
8	29·7	59·4	83·4	69·8	61 0	99·7	65·7	65·6	+16·8	7
9	23·5	26·3	61·8	63·2	45·4	67·7	48·0	49·0	+ 0 2	8
10	16·2	*9·4	38·5	52·7	45·2	43·1	34·2	34·6	−14·2	9
11	6·1	13·3	23·0	38·5	31·4	18·9	21·9	24·6	−24·2	10
12	3·9	59·0	*13·1	21·0	14·7	11·3	20·5	22·5	−26·3	11
13	*2·6	119·3	19·3	7·7	*8·8	7·0	27·5	—	—	—

9. In the above table all the sunspot numbers for the maximum years 1816, 1829, 1837, 1848, 1860, and 1870, are in the *sixth* horizontal line, and the places and the numbers for the minimum years are denoted by asterisks. The "means" for the thirteen terms or series of years are given in the eighth column, and they show that the sunspots increase from 11·6 in the second term to 100·4 in the sixth, and then decrease to 20·5 in the twelfth. The "mean cycle" in the next column is formed as follows:—a, b, c, &c., being the first, second, third, &c., terms of the "means"; the numerical value of $\frac{a+2b+c}{4}$ is made the first term of the "mean cycle," the numerical value of $\frac{b+2c+d}{4}$ its second term, and so on. The "variation" in the last column but one is the deviation from the mean value of the "mean cycle."

10. With the exception of 1833 and 1867, which are respectively in the third and tenth horizontal lines, the years of minimum sunspots are all in the first, second, twelfth, and thirteenth lines (or terms), and all the minimum sunspot numbers, except those for 1833, contribute to the formation of the first and eleventh terms of the "mean cycle." It would be better not to have the sunspot numbers for 1836 in the thirteenth line; but their position cannot be altered without altering the position of the maximum year 1829, and the main object of this table is to obtain approximate values of the sunspots for the mean maximum year, and for one or two years on either side of it.

11. Some of the years are necessarily repeated in the succeeding series, but this does not materially affect the "means" or the "mean cycle," the average of the latter being 48·8, while the average value of the sunspots for the whole period (1811–67) is 46·9.

12. It will be seen that the "mean cycle" exhibits a well-marked sunspot variation. Now if the sunspots are numerically related to the rainfall, an exactly similar treatment of the rainfall should give a rainfall variation, corresponding, either directly or inversely, with the sunspot variation.

13. In the next table the sunspot numbers for the minimum years 1823, 1833, 1843, 1856, and 1867, are all in the *eighth* line, and the places and numbers for the maximum years are marked with asterisks.

TABLE II.—Sunspot numbers.—Minimum years in 8th line.

Years	1816–28	1826–38	1836–48	1849–61	1860–72	Means	Mean Cycle	Variation	Years of Cycle
1	*46·9	35·0	119·3	95·4	*94·8	78·3	—	—	—
2	39·9	51·2	*136·9	69·8	77·7	75·1	73·1	+23·3	1
3	29·7	62·1	104·1	63·2	61·0	64·0	64·3	+14·5	2
4	23·5	*67·2	83·4	52·7	45·4	54·4	54·6	+ 4·8	3
5	16·2	67·0	61·8	38·5	45·2	45·7	44·2	− 5·6	4
6	6·1	59·4	38·5	21·0	31·4	31·3	30·8	−19·0	5
7	3·9	26·3	23·0	7·7	14·7	15·1	17·3	−32·5	6
8	**2·6**	**9·4**	**13·1**	**5·1**	**8·8**	**7·8**	**12·7**	**−37·1**	**7**
9	8·1	13·3	19·3	22·9	36·8	20·1	24·4	−25·4	8
10	16·2	59·0	38·3	56·2	78·6	49·7	51·6	+ 1·8	9
11	35·0	119·3	59·6	90·3	*131·8	87·2	80·7	+30·9	10
12	51·2	*136·9	97·4	*94·8	113·8	98·8	94·6	+44·8	11
13	62·1	104·1	*124·9	77·7	99·7	93·7	—	—	—

The table has been formed in the way in which Table I. has been formed.

All the maximum years except 1829 contribute to the formation of the first and eleventh terms of the mean cycle.

The mean of the mean cycle is 49·8, and the mean for the whole period (1816–72) is 51·3.

As in Table I., the mean cycle exhibits a well-marked variation, the sunspots decreasing to the seventh year, and then increasing to the eleventh.

If, then, the sunspots and the rainfall are numerically related, a corresponding variation should be found for the rainfall, when similarly treated.

II.—Rainfall of Great Britain compared with the Sunspots.

14. The rainfall of Great Britain, as represented by returns from fifty-four stations in different parts of the country, is given in Table III.

The following table has been prepared in the same way as Table I. (Sunspots), and it will be seen from the last two columns but one that the rainfall and sunspot variations are remarkably similar, the rainfall increasing from the first to the sixth year of the cycle, and then decreasing to the eleventh.

The *same* stations have been used in finding the annual mean rainfalls for each series of thirteen years.

The mean of the mean cycle is 31·4 inches, and the mean rainfall from 1824 to 1867 is 31·2 inches.

The range of variation is about 3·7 inches.

The epoch of maximum rainfall occurs about one year after the epoch of maximum sunspots.

The spot variation has been derived from Table I.

15. An important advantage of the above arrangement is that the columns of "means" enable us to compare directly the mean of the sunspot numbers for the maximum years with the mean rainfall for the same

TABLE III.—Great Britain.—Maximum years in 6th line.

No. of Stations	10	18	31	30	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
Years	1824–36	1832–44	1843–55	1855–67					
	in.	in.	in.	in.	in.	in.	in.		
1	30·9	26·4	31·8	27·1	29·1	—	—	—	—
2	26·6	29·4	26·9	35·0	29 5	29·2	− 2·2	− 37·2	1
3	23·7	25·8	33·3	32·5	28·8	29·7	− 1·7	− 22·8	2
4	29·5	29·0	35·1	34·1	31·9	31·4	0·0	+ 4·4	3
5	33·0	34·2	28·6	37·0	33·2	32·6	+ 1·2	+ 33 0	4
6	**28·7**	**26·2**	**37·3**	**36·1**	**32·1**	**32·5**	**+ 1·1**	**+ 43·8**	**5**
7	30·8	28·4	30·6	40·7	32·6	32·9	+ 1·5	+ 32·9	6
8	32·3	32·1	29·9	42·7	34·2	32·7	+ 1·3	+ 14·3	7
9	26·2	25·3	29 3	38·2	29·7	32·1	+ 0·7	− 2·9	8
10	29·7	34·1	39·1	36·1	34·8	31·8	+ 0·4	− 16·6	9
11	24·5	24·9	30·9	32·5	28·2	30·7	− 0·7	− 24·7	10
12	28·6	29·7	28·4	40·0	31·6	30·3	− 1·1	− 24·0	11
13	33·5	24·3	25·5	37·1	30·1	—	—	—	—

years, and also the sunspots with the rainfall for two years on either side of the maximum years, with very little risk of distortion from the minimum years not being all in the same horizontal line.

16. With regard to the way in which the "mean cycle" is formed, it may be remarked that b in the expression $\frac{a+2b+c}{4}$ (see par. 8) gets double weight, and that the quotient is put down as the rainfall of the first year of the "mean cycle," which year corresponds with the second of the thirteen terms or series of years, that is, with b. This is somewhat similar to the common practice of tracing with the hand an approximate average curve through the peaks and hollows of a jagged or serrated curve.

17. An example of the converse process, namely, that of placing the minimum years in the eighth line or term, is given in the following Table, which has been constructed from the annual mean rainfalls of ten stations, "widely separated," as given by Mr. Symons, in the 'Report of the British Association for 1865.'

Table IV. has been constructed in the same way as Table II. (Sunspots).

Now it would appear that on the whole the rainfall attained its minimum a year or two after the epoch of minimum sunspots.

In fact, both this table and Table III. show that the rainfall lags behind the sunspots in respect of time.

The mean of the mean cycle is 28·1 inches, and the mean for the whole period (1816–61) is 28·3 inches.

From the column of "means" we see that although the rainfall was

above the average in the mean minimum year, yet it was below the average in the previous and two following years, thus forming, on the whole, around the minimum year, as shown in the "mean cycle," a group of four or five years in which the rainfall was below the average; and the mean rainfall for these years is scarcely affected by the positions

TABLE IV.—Great Britain.—Minimum years in 8th line.

Years	1816–28	1826–38	1836–48	1849–61	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.		
1	29·3	23·7	33·5	28·5	28.7	—	—	—	—
2	29·7	29·5	24·5	26·3	27·5	28·2	+ 0·1	+ 24·3	1
3	30·3	33·0	27·1	26·7	29·3	29·4	+ 1·3	+ 17·5	2
4	30·4	28·7	31·3	35·5	31·5	29·7	+ 1·6	+ 8·4	3
5	24·5	30·8	24·7	27·4	26·8	28·6	+ 0·5	— 2·7	4
6	29·9	32·3	33·5	22·4	29·5	27·8	– 0·3	—16·8	5
7	26·6	26·2	25·5	23·4	25·4	27·4	– 0·7	— 30·4	6
8	**31·1**	**29·7**	**30·4**	**25·9**	**29·3**	**27·5**	**– 0·6**	**—36·1**	**7**
9	30·9	24·5	23·7	25·7	26·2	27·0	– 1·1	— 27·2	8
10	26·6	28·5	27·9	22·8	26·4	26·9	— 1·2	— 3·5	9
11	23·7	33·5	29·6	28·5	28·8	28·0	— 0·1	+ 24·7	10
12	29·5	24·5	25·8	33·3	28·3	29·0	+ 0·9	+ 42·0	11
13	33·0	27·1	36·0	27·0	30·8	—	—	—	—

occupied in the table by the maximum years. It is to be remarked, also, that if a greater number of stations were taken, as in Table III., it would be found that the rainfall in the mean minimum year is *below* the average; but it was desirable to adopt Mr. Symons's figures alone, because they furnish independent evidence of a rainfall cycle, even for a small number of stations.

On the other hand we have, around the mean maximum year in Table III., a group of five or six years in which the rainfall is above the average.

From these two tables (III. and IV.) it is concluded that there is strong evidence of a rainfall cycle for Great Britain.

18. I will now compare with the sunspots the rainfall of Edinburgh, as given in the 'Journal of the Scottish Meteorological Society.'

TABLE V.—Edinburgh.—Maximum years in 6th line.

Years	1824–36	1832–44	1843–55	1855–67	Means	Mean Cycle	Rain Var.	Spot Var.	Year of Cycle
	in.	in.	in.	in.	in.	in.	in.		
1	24·8	23·2	23·8	20·3	23·0	—	—	—	—
2	22·1	20·9	20·9	28·5	23·1	22·8	– 2·8	– 37·2	1
3	15·3	21·0	26·6	24·9	22·0	23·8	– 1·8	– 22·8	2
4	32·6	25·2	31·5	24·3	28·4	26·3	+ 0·7	+ 4·4	3
5	25·2	33·0	22·8	25·9	26·7	28·0	+ 2·4	+ 33·0	4
6	**30·0**	**26·8**	**30·6**	**33·4**	**30·2**	**28·9**	**+3·3**	**+43·8**	**5**
7	33·2	31·0	22·2	28·6	28·8	28·4	+ 2·8	+ 32·9	6
8	24·5	23·4	21·3	33·9	25·8	26·1	+ 0·5	+ 14·3	7
9	23·2	25·5	22·8	25·6	24·3	25·2	– 0·4	– 2·9	8
10	20·9	26·2	31·5	28·1	26·7	24·6	– 1·0	– 16·6	9
11	21·0	16·9	21·8	23·6	20·8	23·1	– 2·5	– 24·7	10
12	25·2	23·8	20·9	27·2	24·3	23·9	– 1·7	– 24·0	11
13	33·0	20·9	20·3	31·0	26·3	—	—	—	—

Here we have a remarkable parallelism, both the sunspots and the rainfall attaining their maximum and minimum in the same years, and rising and falling together with considerable regularity.

The mean of the mean cycle is 25·6 inches, and the mean rainfall is 25·7 inches.

19. The next table gives the results of the converse arrangement for the rainfall of Edinburgh.

TABLE VI.—Edinburgh.—Minimum years in 8th line.

Years	1826–38	1836–48	1849–61	1860–72	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.		
1	15·3	33·0	22·2	33·4	26·0	—	—	—	—
2	32·6	26·8	21·3	28·6	27·3	27·2	+ 1·2	+ 24·7	1
3	25·2	31·0	22·8	33·9	28·2	27·8	+ 1·8	+ 15·9	2
4	30·0	23·4	31·5	25·6	27·6	27·6	+ 1·6	+ 5·6	3
5	33·2	25·5	21·8	28·1	27·2	26·4	+ 0·4	+ 5·4	4
6	24·5	26·2	20 9	23·6	23·8	24·1	– 1·9	– 20·4	5
7	23·2	16·9	20 3	27·2	21·9	23·4	– 2·6	– 36·3	6
8	**20·9**	**23·8**	**28·5**	**31·0**	**26·0**	**24·4**	**– 1·6**	**–42·1**	**7**
9	21·0	20·9	24·9	28·6	23·8	24·6	– 1·4	– 28·6	8
10	25·2	26·6	24 3	22·2	24·6	25·2	– 0·8	+ 2·9	9
11	33·0	31·5	25·9	22·1	28·1	26·8	+ 0·8	+ 35·3	10
12	26·8	22·8	33·4	23·2	26·4	28·2	+ 2·2	+ 48·9	11
13	31·0	30·6	28·6	38·2	32·1	—	—	—	—

We have here also a remarkable parallelism, but not quite so much so as in Table V.

The rainfall reaches its minimum in the year before that of minimum sunspots.

The mean of the mean cycle is 26·0 inches, and the mean rainfall is also 26·0 inches.

The variation range is about 6 inches, the rainfall being 3·3 inches above the mean in Table V., and 2·6 inches below it in Table VI.

20. Similar results might be given for the rainfalls of other individual stations in Great Britain, but it is unnecessary to do so. For the present it is sufficient to know that the annual mean falls at fifty-four stations, virtually obtained at haphazard, as well as the mean annual falls at Mr. Symons's ten stations, which were selected by him for a different purpose, show, on the whole, a well-marked rainfall cycle corresponding with the sunspot cycle.

21. The rainfall of Greenwich, although greater in the maximum than in the minimum years of sunspots, is not nearly so favourable as the rainfalls of Edinburgh and other stations.

III.—Rainfall of the Continent of Europe compared with the Sunspots.

22. Through the kindness of Mr. Estourgies and the Directors of various Observatories, I obtained some time ago returns of the rainfalls at forty-five stations dispersed over the Continent of Europe. The results, according to the method adopted on this occasion, are given in the next two tables.

As at Edinburgh, the year of maximum rainfall coincides with the year of maximum sunspots.

The mean rainfall for the mean cycle is 26·6 inches, and for the whole period (1824–67) 26·8 inches.

Owing to some heavy floods in 1844, 1855, and 1867, the rainfall for the eleventh year of the mean cycle is somewhat above the average.

TABLE VII.—Continent of Europe.—Maximum years in 6th line.

No. of Stations	4	19	20	30	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
Years	1824–36	1832–44	1843–55	1855–67					
	in.	in.	in.	in.	in.	in.	in.		
1	27·7	22·5	29·1	27·2	26·6	—	—	—	—
2	22·8	28·8	30·0	25·1	26·6	25·8	– 0·8	– 37·2	1
3	21·4	22·0	31·3	19·7	23·6	24·8	– 1·8	– 22·8	2
4	27·0	24·1	29·8	22·1	25·7	25·3	– 1·3	+ 4 4	3
5	25·6	27·6	26·7	26·1	26·5	27·0	+ 0·4	+ 33·0	4
6	**29·3**	**28·7**	**30·5**	**29·4**	**29·5**	**27·8**	**+ 1·2**	**+ 43·8**	**5**
7	23·0	27·8	27·2	25·1	25·8	27·6	+ 1·0	+ 32·9	6
8	29·4	30·7	31·2	26·2	29·4	27·7	+ 1·1	+ 14·3	7
9	22·1	27·9	30·6	24·5	26·3	27·2	+ 0·6	– 2·9	8
10	27·7	28·5	28·2	23·4	26·9	26·1	– 0·5	– 16·6	9
11	19·9	26·1	29·6	22·5	24·5	25·8	– 0·8	– 24·7	10
12	25·3	30·3	27·0	27·1	27·4	27·2	+ 0·6	– 24·0	11
13	27·6	30·5	30·7	29·3	29·5	—	—	—	—

23. The converse arrangement of the yearly rainfall at eleven stations gives the following results.

TABLE VIII.—Continent of Europe.—Minimum years in 8th line.

Years	1836–48	1849–61	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	m.m.	m.m.	m.m.	m.m.	m.m.		
1	660	668	664	—	—	—	—
2	717	817	767	726	+ 40	+ 44·7	1
3	676	736	706	718	+ 32	+ 30·0	2
4	739	648	693	694	+ 8	+ 12·8	3
5	685	681	683	677	– 9	– 5·2	4
6	647	656	651	665	– 21	– 23·4	5
7	611	744	677	677	– 9	– 37·3	6
8	**756**	**650**	**703**	**676**	**– 10**	**– 41·0**	**7**
9	743	499	621	653	– 33	+ 30·0	8
10	735	603	669	665	– 21	+ 7·0	9
11	714	692	703	698	+ 12	+ 18·6	10
12	704	735	719	700	+ 14	+ 37·5	11
13	687	636	661	—	—	—	—

The above table has been derived from a paper by the late Dr. Carl Ielinek, of Vienna, published in the 'Zeitschrift der Oesterreichischen für Meteorologie,' for March, 1873, in which the rainfalls at fourteen stations are given. Three of these stations, the returns for which are not complete, have not been used in forming the table.

The mean rainfall for the mean cycle and also for the whole period (1836–61) is 686 m.m.

The rainfall was at its minimum (33 m.m. below the mean) in the year after the year of minimum sunspots, and at its maximum when the sunspots were at their maximum.

Considering that there are only two sunspot periods, the results may be regarded as favourable. The rainfall and sunspots were both above (+) or below (—) their respective means in the same years.

I have used Dr. Ielinek's table in preference to a more extensive one, because, like Mr. Symons's table, it furnishes independent evidence.

24. In the next two tables the rainfall of Paris is compared with the sunspots. The series of observations at this station is so long that eight complete sunspot cycles might be taken, but, as objection has been made to going back much farther than the time when Schawbe commenced his observations, only four cycles are taken in one of these tables, and five in the other.

TABLE IX.—Paris.—Maximum years in 6th line.

Years	1824–36	1832–44	1843–55	1855–67	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	m.m.	m.m.	m.m.	m.m.	m.m.	m m.	m.m.		
1	572	456	542	344	478	—	—	—	—
2	469	503	571	565	527	502	– 11	– 37·2	1
3	410	421	581	492	476	493	– 20	– 22·8	2
4	501	438	564	466	492	501	– 12	+ 4·4	3
5	585	611	430	545	543	541	+ 28	+ 33 0	4
6	**560**	**548**	**575**	**655**	**584**	**563**	**+ 50**	**+ 43·8**	**5**
7	573	542	597	458	543	554	+ 41	+ 32·9	6
8	529	580	563	516	547	522	+ 9	+ 14 3	7
9	456	455	469	426	452	487	– 26	– 2·9	8
10	503	527	597	366	498	472	– 41	– 16 6	9
11	421	342	454	542	440	484	– 29	– 24·7	10
12	438	542	614	644	559	520	+ 7	– 24·0	11
13	611	571	344	565	523	—	—	—	—

The maximum rainfall coincides with the maximum sunspots.

The mean of the mean cycle is 513 m.m., and the mean rainfall for the whole period (1824–67) is 517 m.m.

As in the case of the annual means for forty-five stations (Table VII.), the rainfall is somewhat above the mean in the eleventh year of the cycle.

25. The converse process is given in the following table.

TABLE X.—Paris.—Minimum years in 8th line.

Years	1816–28	1826–38	1836–48	1849–61	1860–72	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	m.m.	m.m.	m m.	m.m.	m.m.	m.m.	m.m.	m.m.		
1	546	410	611	597	655	564	—	—	—	—
2	565	501	548	563	458	527	531	+ 20	+ 23·3	1
3	432	585	542	469	516	509	525	+ 14	+ 14 5	2
4	615	560	580	597	426	556	516	+ 5	+ 4·8	3
5	378	573	455	454	366	445	501	– 10	– 5·6	4
6	584	529	527	614	542	559	501	– 10	– 19·0	5
7	424	456	342	344	644	442	492	– 19	– 32 5	6
8	**457**	**503**	**542**	**565**	**565**	**526**	**502**	**– 9**	**– 37·1**	**7**
9	572	421	571	492	512	514	510	– 1	– 25·4	8
10	469	438	581	466	477	486	499	– 2	+ 1·8	9
11	410	611	564	545	418	510	510	– 1	+ 30·9	10
12	501	548	430	655	527	532	535	+ 24	+ 44·8	11
13	585	542	575	458	671	566	—	—	—	—

The rainfall decreases till the sixth year of the mean cycle, that is, the year before that of minimum sunspots, and then increases to the eleventh year.

The mean of the mean cycle is 511 m.m., and the mean rainfall from 1816 to 1872 is 515 m.m.

26. As another example of the rainfall variation at a single station on the Continent of Europe, I will take Prague from 1832 to 1867.

TABLE XI.—Prague.—Maximum years in 6th line.

Years	1832–44	1843–55	1855–67	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.		
1	10·8	17·5	17·7	15·3	—	—	—	—
2	19·3	23·6	14·9	19·3	17·0	+ 0·5	– 42·1	1
3	10·1	17·5	14·9	14·2	15·6	– 0·9	– 27·5	2
4	10·4	18·5	15·5	14·8	15·8	– 0·7	+ 3·5	3
5	16·6	23·3	19·1	19·7	18·2	+ 1·7	+ 38·2	4
6	**18·6**	**16·9**	**20·6**	**18·7**	**18·2**	**+ 1·7**	**+ 50·9**	**5**
7	15·9	15·7	16·5	16·0	17·5	+ 1·0	+ 36·5	6
8	18·6	20·5	18·9	19·3	17·6	+ 1·1	+ 16·3	7
9	14·6	18·4	14·7	15·9	16·3	– 0·2	+ 0·5	8
10	18·8	14·5	9·4	14·2	14·4	– 2·1	– 12·5	9
11	9·4	18·6	12·1	13·4	14·5	– 2·0	– 26·3	10
12	17·5	16·4	17·5	17·1	16·6	+ 0·1	– 38·4	11
13	23·6	17·7	15·5	18·9	—	—	—	—

The maximum rainfall coincides with the maximum sunspots.

The mean rainfall for the mean cycle is 16·5 inches, and 16·6 inches for the period 1832–67.

The variation is less regular than at Edinburgh and Paris, but we have only three periods.

27. The next table shows the converse rainfall variation for Prague.

TABLE XII.—Prague.—Minimum years in 8th line.

Years	1836–48	1849–61	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.		
1	16·6	15·7	16·1	—	—	—	—
2	18·6	26·5	22·5	19·5	+ 2·0	+ 48·8	1
3	15·9	18·4	17·1	18·0	+ 0·5	+ 29·6	2
4	18·6	14·5	16·5	16·6	– 0·9	+ 12·4	3
5	14·6	18·6	16·6	16·8	– 0·7	– 0·6	4
6	18·8	16·4	17·6	16·3	– 1·2	– 23·8	5
7	9·4	17·7	13·5	15·2	– 2·3	– 37·7	6
8	**17·5**	**14·9**	**16·2**	**16·2**	**–1·3**	**–41·4**	**7**
9	23·6	14·9	19·2	17·7	+ 0·2	– 30·5	8
10	17·5	15·5	16·5	17·7	+ 0·2	– 7·5	9
11	18·5	19·1	18·8	19·0	+ 1·5	+ 18·2	10
12	23·3	20·6	21·9	19·8	+ 2·3	+ 37·1	11
13	16·9	16·5	16·7	—	—	—	—

On the whole the rainfall decreases to the sixth year of the cycle, and then increases to the eleventh.

The mean of the mean cycle is 17·5 inches, and the mean rainfall from 1836 to 1861 is 17·4 inches.

IV.—The Levels of Rivers of Central Europe compared with the Sunspots.

28. A paper by Herr Gustav Wex, 'On the Decrease of Water in the Wells, Streams, and Rivers,' published in 1873, contains a number of Tables, giving the yearly mean heights (or depths) of water in the Elbe, Rhine, Oder, Vistula, and Danube, for various periods from 1728 to 1871.

Having been favoured with a copy of that important paper, I have compared the annual mean levels of the rivers with the sunspots, in the same manner as the rainfall has been compared, and the results are given in the next five tables.

TABLE XIII.—Depths of Rivers.—Maximum years in 6th line.

Years	1799 to 1811	1811–23	1824–36	1832–44	1843–55	1855–67	Means	Mean Cycle	River Var.	Spot Var.	Years of Cycle
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.		
1	8 0·2	4 10·8	6 8·7	4 11·0	6 1·3	7 2·5	6 3·7	—	—	—	—
2	5 0·7	6 5·1	6 4·3	6 0·2	7 3·0	4 11·1	6 0·1	6 0·9	0 0·0	− 26·2	1
3	7 7·6	6 8·3	5 9·4	5 6·4	6 6·2	3 8·2	5 11·7	5 10·7	− 0 2·2	− 14·1	2
4	6 6·4	6 2·8	6 6·3	4 0·7	6 4·2	4 0·9	5 7·6	5 9·3	− 0 3·6	+ 5·4	3
5	6 8·4	6 4·8	7 0·2	4 9·0	6 0·3	4 3·8	5 10·4	6 2·0	+ 0 1·1	+ 26·1	4
6	**8 7·2**	**8 6·5**	**8 8.8**	**7 2·1**	**4 6·6**	**6 2·8**	**7 3·7**	**6 9·3**	**+ 0 8·4**	**+ 34·7**	**5**
7	8 3·9	7 6·9	7 5·5	6 6·6	5 0·5	4 7·1	6 7·1	6 9·2	+ 0 8·3	+ 25·9	6
8	8 1·7	6 0·9	7 4·5	7 3·6	6 9·9	3 7·6	6 6·7	6 4·4	+ 0 3·5	+ 9·9	7
9	7 1·2	5 10·2	4 11·0	7 4·7	6 8·5	2 6·1	5 9·0	5 10·6	− 0 2·3	− 3·7	8
10	6 7·5	6 0·8	6 0·2	6 2·0	5 7·5	4 4·8	5 9·8	5 9·6	− 0 3·3	− 14·1	9
11	7 10·1	7 8·1	5 6·4	3 8·2	6 8·7	3 5·8	5 9·9	5 7·9	− 0 5·0	− 21·2	10
12	6 3·9	5 5·3	4 0·7	6 5·0	5 10·0	2 11·3	5 2·0	5 7·7	− 0 5·2	− 22·9	11
13	5 8·1	5 7·7	4 9·0	8 7·6	7 2·5	6 4·6	6 4·6	—	—	—	—

From 1799 to 1811 we have (in Austrian feet and inches) the levels of the Rhine, Elbe, and Oder; from 1811 to 1823 those of the Rhine, Elbe, Oder, and Vistula; from 1824 to 1844 those of the Elbe and Vistula; and from 1843 to 1867 those of the Elbe, Vistula, and Danube.

As might have been expected from the results for the rainfall of Europe (Table VII.), the maximum height or level was attained in the mean year of maximum sunspots, and, as a rule, the rivers fluctuated with the sunspots.

The mean of the mean cycle is 6 ft. 0·9 inches, and for the whole period (1799 to 1867) the mean is 6 ft. 1·8 inches.

If we omit the years 1799 to 1811, as being in the opinion of some too early, we still get similar results, and likewise similar results for the still later periods 1824–67.

29. The converse process gives the following results:—

In the next table we have the Rhine, Elbe, and Oder from 1804 to 1816; the Rhine, Elbe, Oder, and Vistula from 1817 to 1829; the Elbe and Vistula from 1827 to 1839; the Elbe, Vistula, and Danube from 1850 to 1862; and the Vistula and Danube from 1861 to 1871.

The levels in the years of minimum sunspots are placed in the seventh line, because the river variation was found to overlap the sunspot variation to a considerable extent.

TABLE XIV.—Depths of Rivers.—Minimum years in 7th line.

Years	1804–16	1817–29	1827–39	1837–49	1850–62	1861–71	Means	Mean Cycle	River Var.	Spot Var.	Years of Cycle
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.		
1	8 7·2	7 6·9	6 6·3	7 2·1	8 8·0	4 2·2	7 1·4	—	—	—	—
2	8 3·9	6 0·9	7 0·2	6 6·6	8 4·6	3 1·5	6 6·9	6 8·2	+ 0 5·6	+ 16·4	1
3	8 1·7	5 10·2	8 8·8	7 3·6	7 1·6	1 9·0	6 5·8	6 7·5	+ 0 4·9	+ 5·3	2
4	7 1·2	6 0·8	7 5·5	7 4·7	9 6·1	4 4·8	6 11·8	6 8·6	+ 0 6·0	− 5·4	3
5	6 7·5	7 8·1	7 4·5	6 2·0	7 6·3	3 3·4	6 5·3	6 4·2	+ 0 1·6	− 17·7	4
6	6 10·5	5 5·3	4 11·0	3 8·2	9 9·5	2 6·7	5 6·5	5 10·7	− 0 3·9	− 27·6	5
7	**5 7·8**	**5 7·7**	**6 0·2**	**6 5·0**	**6 5·5**	**6 2·5**	**6 0·8**	**5 11·4**	**− 0 3·2**	**− 31·0**	**6**
8	5 3·6	6 10·7	5 6·4	8 7·6	5 6·7	4 10·7	6 1·6	5 11·3	− 0 3·3	− 21·8	7
9	6 5·3	5 11·5	4 0·7	7 1·2	5 5·1	3 8·6	5 5·4	5 8·1	− 0 6·5	+ 0·4	8
10	6 2·9	5 2·7	4 9·0	7 5·3	5 9·1	5 8·2	5 10·2	5 11·4	− 0 3·2	+ 23·8	9
11	5 11·3	6 7·8	7 2·1	5 11·6	8 6·3	5 8·9	6 8·0	6 3·4	+ 0 0·8	+ 33·2	10
12	5 10·0	6 8·4	6 6·6	4 7·8	6 0·2	—	5 11·4	6 3·6	+ 0 1·0	+ 30·0	11
13	8 1·7	8 0·0	7 3·6	5 4·5	4 5·1	—	6 7·8	—	—	—	—

The lowest level is attained two years after the mean year of minimum sunspots.

The mean of the mean cycle is 6 ft. 2·6 inches, and for the years 1804 to 1871 the mean level is 6 ft. 3·6 inches.

30. Taking the Elbe alone, we get the following results:—

TABLE XV.—Depths of the Elbe.—Maximum years in 6th line.

Years	1824–36	1832–44	1843–55	1855–67	Means	Mean Cycle	River Var.	Spot Var.	Years of Cycle
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.		
1	6 11·0	5 0·0	7 2·0	7 7·0	6 8·0	—	—	—	—
2	6 3·2	6 4·0	7 9·0	6 0·0	6 7·0	6 4·1	+0 3·1	− 37·2	1
3	5 7·3	5 8·7	6 4·0	4 7·0	5 6·7	5 10·0	−0 3·0	− 22·8	2
4	7 1·4	4 1·5	6 4·0	5 0·0	5 7·7	5 8·6	−0 4·4	+ 4·4	3
5	7 8·2	4 9·0	6 9·0	5 0·0	6 0·6	6 1·4	+0 0·4	+ 33·0	4
6	**7 11·4**	**7 2·0**	**5 3·0**	**6 7·0**	**6 8·9**	**6 6·3**	**+0 5·3**	**+ 43·8**	**5**
7	7 8·0	7 0·0	5 10·0	5 10 0	6 7·0	6 8·7	+0 7·7	+ 32·9	6
8	8 0·0	7 6·0	7 5·0	5 2·0	7 0·2	6 7·2	+0 6·2	+ 14·3	7
9	5 0·0	5 11·0	7 7·0	4 9·0	5 9·7	6 1·5	+0 0·5	− 2·9	8
10	6 4·0	6 5·0	6 5·0	4 5·0	5 10·7	5 8·4	−0 4·6	− 16·6	9
11	5 8·7	4 5·0	6 8·0	4 1·0	5 2·7	5 5·8	−0 7·2	− 24·7	10
12	4 1·5	7 2·0	7 0·0	4 1·0	5 7·1	5 9·4	−0 3·6	− 24·0	11
13	4 9·0	7 9·0	7 7·0	6 11·0	6 9·0	—	—	—	—

The mean maximum level (6 ft. 8·7 inches) is attained soon after the maximum sunspots.

The mean depth for the mean cycle is 6 ft. 1·0 inches, and for the whole period 6 ft. 2·2 inches.

31. The converse arrangement gives the following results for the Elbe:—

The lowest mean level occurs about two years after the epoch of minimum sunspots (as in Table XIV.), and there is a considerable amount of overlapping, the river lagging behind the sunspots.

The mean for the mean cycle is 6 ft. 4·7 inches, and also 6 ft. 4·7 inches for the years 1816 to 1861.

TABLE XVI.—Depths of the Elbe.—Minimum years in 8th line.

Years	1816–28	1826–38	1836–48	1849–61	Means	Mean Cycle	River Var.	Spot Var.	Years of Cycle
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.		
1	7 3·5	5 7·3	4 9·0	5 10·0	5 10·4	—	—	—	—
2	6 7·6	7 1·4	7 2·0	7 5·0	7 1·0	6 8·7	+0 4·0	+ 24·3	1
3	5 2·8	7 8·2	7 0·0	7 7·0	6 10·5	7 0·2	+0 7·5	+ 17·5	2
4	7 0·7	7 11·4	7 6·0	6 5·0	7 2·8	6 11·1	+0 6·4	+ 8·4	3
5	5 3·2	7 8·0	5 11·0	6 8·0	6 4·5	6 9·5	+0 4·8	− 2·7	4
6	7 4·9	8 0·0	6 5·0	7 0·0	7 2·5	6 7·5	+0 2·8	− 16·8	5
7	5 10·6	5 0·0	4 5·0	7 7·0	5 8·6	6 2·6	−0 2·1	− 30·4	6
8	**5 5·4**	**6 4·0**	**7 2·0**	**6 0·0**	**6 2·8**	**6 1·3**	**−0 3·4**	**− 36·1**	**7**
9	6 11·0	5 8·7	7 9·0	4 7·4	6 3·0	6 0·5	−0 4·2	− 27·2	8
10	6 3·2	4 1·5	6 4·0	5 0·0	5 5·2	5 7·6	−0 9·1	− 3·5	9
11	5 7·3	4 9·0	6 4·0	5 0·0	5 5·1	5 9·5	−0 7·2	+ 24·7	10
12	7 1·4	7 2·0	6 9·0	6 7·0	6 10·8	6 5·0	+0 0·3	+ 42·0	11
13	7 8·2	7 0·0	5 3·0	5 10·0	6 5·3	—	—	—	—

32. The next table gives the fluctuations of the Rhine from 1799 to 1835.

TABLE XVII.—Depths of Rhine.—Maximum years in 6th line.

Years	1799 to 1811	1811–23	1824–36	Means	Mean Cycle	River Var.	Spot Var.	Years of Cycle
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.		
1	10 7·0	8 1·5	11 3·4	10 0·0	—	—	—	—
2	6 10·0	9 0·2	8 4·2	8 0·8	8 7·6	− 0 2·8	− 13·6	1
3	11 0·0	8 1·4	6 1·4	8 4·9	8 5·8	− 0 4·6	− 2·0	2
4	8 10·5	8 6·0	9 9·3	9 0·6	8 8·1	− 0 2·3	+ 10·3	3
5	8 5·0	7 11·4	8 3·4	8 2·6	9 0·5	+ 0 2·1	+ 20·9	4
6	**10 8·5**	**12 4·2**	**9 0·1**	**10 8·3**	**10 0·1**	**+1 1·7**	**+25·6**	**5**
7	10 5·0	11 4·1	9 7·4	10 5·5	10 5·0	+ 1 6·6	+ 19·3	6
8	11 11·5	8 3·4	10 11·3	10 0·7	9 5·3	+ 0 6·9	+ 5·2	7
9	9 2·0	6 7·0	5 10·5	7 2·5	8 2·6	− 0 7·8	− 8·7	8
10	9 3·0	7 6·1	8 3·2	8 4·1	8 2·6	− 0 7·8	− 18·3	9
11	10 3·0	10 0·6	6 7·8	8 11·8	8 5·0	− 0 5·4	− 19·6	10
12	8 6·0	6 11·7	6 7·5	7 4·4	7 11·8	−0 10·6	− 18·9	11
13	8 1·5	8 4·0	—	8 2·7	—	—	—	—

The Rhine attained its mean maximum level about one year after the year of maximum sunspots.

The mean of the mean cycle is 8 ft. 10·4 inches, and the mean for 1799 to 1836 is 8 ft. 8·2 inches.

V.—Rainfall of America compared with the Sunspots.

33. The rainfall returns for America, thirty-four in number, have been obtained from 'Tables and Results of the Precipitation in Rain and Snow,' published by the Smithsonian Institution (Washington, 1872).

TABLE XVIII.—Rainfall of America.—Maximum years in 6th line.

No. of Stations	2	10	28	10	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
Years	1824–36	1832–44	1843–55	1855–67					
	in.	in.	in.	in.	in.	in.	in.		
1	39·0	40·9	42·9	42·4	41·3	—	—	—	—
2	33·1	39·6	37·4	35·6	36·5	38·8	− 2·8	− 37·2	1
3	45·2	35·3	38·2	46·0	41·2	40·6	− 1·0	− 22·8	2
4	50·1	36·7	41·5	46·0	43·6	42·5	+ 0·9	+ 4·4	3
5	34·3	39·1	45·5	47·7	41·6	42·1	+ 0·5	+ 33·0	4
6	**53·1**	**35·4**	**40·0**	**37·8**	**41·6**	**41·8**	**+ 0·2**	**+ 43·8**	**5**
7	51·0	37·3	39·0	42·4	42·4	42·9	+ 1·3	+ 32·9	6
8	52·6	37·2	46·5	44·4	45·2	43·6	+ 2·0	+ 14·3	7
9	45·2	40 2	36·7	44·3	41·6	42·4	+ 0·8	− 2·9	8
10	38·8	43·8	43·1	39·2	41·2	41·3	− 0·3	− 16·6	9
11	39·1	41·5	39·9	44·0	41·1	40·9	− 0·7	− 24·7	10
12	38·7	42·5	38·9	40·7	40·2	40·2	− 1·4	− 24·0	11
13	38·1	36·2	41·1	42·8	39·5	—	—	—	—

The maximum rainfall occurs about two years after the maximum sunspots.

The mean rainfall for the cycle is 41·6 inches, and for the forty-four years 41.3 inches.

34. From the converse process we get the following table:—

TABLE XIX.—Rainfall at ten stations in America, from 1849 to 1861.—Minimum year in 8th line.

Years	Mean	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.		
1	38·0	—	—	—	—
2	48·8	43·2	+ 1·4	+ 26·9	1
3	37·5	41·2	− 0·6	+ 14·6	2
4	41·3	40·0	− 1·8	+ 4·1	3
5	40·0	40·0	− 1·8	− 10·0	4
6	39·0	40·1	− 1·7	− 25·6	5
7	42·4	39·8	− 2·0	− 37·3	6
8	**35·7**	**39·9**	**− 1·9**	**− 37·4**	**7**
9	46 0	43·4	+ 1·6	− 20·9	8
10	46 0	46·4	+ 4·6	+ 8·8	9
11	47·7	44·8	+ 3·0	+ 35·4	10
12	37·8	41·4	− 0·4	+ 41·8	11
13	42·4	—	—	—	—

The minimum rainfall took place at the time of minimum sunspots.

The mean of the mean cycle is 41·8 inches, and the mean from 1849 to 1861 is 41·7 inches.

35. The longest series of observations was made at New Bedford. Taking the period 1824–67, we get the following results for that station:—

TABLE XX.—Rainfall at New Bedford.—Maximum years in 6th line.

Years	1824–36	1832–44	1843–55	1855–67	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.		
1	42·1	43·8	45·0	36·4	41·8	—	—	—	—
2	33·9	37·9	36·2	33·0	35·2	38·7	− 3·2	− 37·2	1
3	48·7	40·1	42·7	38·6	42·5	40·7	− 1·2	− 22·8	2
4	55·9	42·0	30·7	42·4	42·7	42·1	+ 0·2	+ 4·4	3
5	34·7	38·1	40·8	48·9	40·6	41·5	− 0·4	+ 33·0	4
6	**58·1**	**34·7**	**36·2**	**38·3**	**41·9**	**41·6**	**− 0·3**	**+ 43·8**	**5**
7	57·5	34·0	31·9	44·7	42·0	43·2	+ 1·3	+ 32·9	6
8	54·4	39·4	51·8	41·4	46·7	45·2	+ 3·3	+ 14·3	7
9	43·8	44·1	49·8	44·4	45·5	44·6	+ 2·7	− 2·9	8
10	37·9	45·0	41·0	39·5	40·8	41·5	− 0·4	− 16·6	9
11	40·1	34·7	35·1	44·6	38·6	40·4	− 1·5	− 24·7	10
12	42·0	45·0	47·8	38·5*	43·3	41·1	− 0·8	− 24·0	11
13	38·1	36·2	36·4	45·6	39·1	—	—	—	—

* Interpolated.

The maximum rainfall occurs about two years after the maximum of sunspots, and the minimum rainfall near the time of minimum sunspots.

The mean of the cycle, and also for the period 1824–36, is 41·9 inches.

36. By the converse arrangement, the rainfall of New Bedford is least near the epoch of minimum sunspots, but generally the variation is irregular.

VI.—Rainfall at Stations in India compared with the Sunspots.

As yet the rainfalls of only a few stations in India have been examined.

TABLE XXI.—Rainfalls of India.—Maximum years in 6th line.

No. of Stations	2	3	3	4	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
Years	1824–36	1832–44	1843–55	1855–67					
	in.	in.	in.	in.	in.	in.	in.		
1	33·8	47·7	57·6	42·0	45·3	—	—	—	—
2	64·1	56·4	68·2	55·4	61·0	56·3	− 4·0	- 37·2	1
3	69·6	59·3	51·2	51·7	57·9	61·4	+ 1·1	− 22·8	2
4	84·7	63·2	76·7	50·6	68:8	65·9	+ 5·6	+ 4·4	3
5	79·9	59·4	76·5	57·6	68·4	64·7	+ 4·4	+ 33·0	4
6	**51·2**	**52·5**	**63·1**	**46·7**	**53·4**	**58·8**	**−1·5**	**+43·8**	**5**
7	52·1	52·0	75·1	61·0	60·0	58·8	− 1·5	+ 32·9	6
8	73·0	63·9	54·5	57·1	62·1	60·9	+ 0·6	+ 14·3	7
9	46·2	60·4	73·2	57·7	59 4	60·4	+ 0·1	− 2·9	8
10	54·2	63·3	74·5	51·5	60·9	59·6	− 0·7	− 16·6	9
11	54·7	69·3	50·2	54·8	57·2	58·3	− 2·0	− 24·7	10
12	52·0	57·6	63·9	59·1	58·1	58·0	− 2·3	− 24·0	11
13	66·4	68·2	47·9	53·3	58·9	—	—	—	—

The mean rainfalls of Bombay and Madras are taken from 1824 to 1836; of Bombay, Madras, and Calcutta from 1832 to 1855; and of Bombay, Madras, Calcutta, and Nagpur from 1855 to 1867.

37. In the year of maximum sunspots the rainfall is somewhat below the average, and there seems to be a tendency to a double oscillation of the rainfall during the sunspot period, the principal maximum occurring a

year or so before the epoch of maximum sunspots, with a small minimum and maximum between the principal maximum and the principal minimum. But this apparent irregularity may be owing to the fewness of the observations.

The mean of the mean cycle is 60·3 inches, and of the rainfall for the whole period 59·3 inches.

38. In the next table the rainfall of Madras is omitted, but the general results are still the same.

TABLE XXII.—Rainfall of India.—Maximum years in 6th line.

No. of Stations	1	2	2	3	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
Y	1824–36	1832–44	1843–55	1855–67					
	in.	in.	in.	in.	in.	in.	in.		
1	34·0	62·4	61·3	45·2	50·7	—	—	—	—
2	72·2	66·0	69·5	58·2	66·5	62 0	− 6·3	− 37·2	1
3	78·5	69·6	57·9	51·2	64·3	66·4	− 1·9	− 22·8	2
4	81·0	74·0	75·2	51·4	70·4	71·3	+ 3·0	+ 4·4	3
5	122·0	66·7	74·2	58·4	80·3	72·7	+ 4·4	+ 33·0	4
6	**65·6**	**54·1**	**67·3**	**53·1**	**60·0**	**67·9**	**− 0·4**	**+ 43·8**	**5**
7	71·9	51·9	92·7	69·0	71·4	69·3	+ 1·0	+ 32·9	6
8	101·8	69·3	63·3	63·4	74·4	72·0	+ 3·7	+ 14·3	7
9	74·1	61·2	77·6	58·7	67·9	69·2	+ 0·9	− 2·9	8
10	71·4	65·8	75·3	52·9	66·4	67·2	− 1·1	− 16·6	9
11	70·5	85·6	57·3	59·2	68·2	66·9	− 1·4	− 24·7	10
12	62·6	61·3	74·3	61·7	65·0	66·8	− 1·5	− 24·0	11
13	88·0	69·6	55·8	62·9	69·1	—	—	—	—

39. The next table gives the rainfall of Bombay and Madras from 1816 to 1838; of Bombay, Madras, and Calcutta from 1836 to 1861; and of Bombay, Madras, and Calcutta from 1860 to 1872.

TABLE XXIII.—Rainfall of India.—Minimum years in 8th line.

No. of Stations	2	2	3	3	4	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
Years	1816–28	1826–38	1836–48	1849–61	1860–72					
	in.	in.	in.	in.	in.	in.	in.	in.		
1	55·6	69·6	59·3	75·1	46·7	61·3	—	—	—	—
2	83·6	84·7	52·5	54·5	61·0	67·3	66·0	+ 4·9	+ 23·3	1
3	78 6	79·9	52 0	73·2	57·1	68·2	66·1	+ 5·0	+ 14·5	2
4	57·0	51·2	63·9	74·5	57·7	60·8	61·8	+ 0 7	+ 4·8	3
5	73·6	52·1	60 4	50·2	51·5	57·6	59·9	− 1·2	− 5·6	4
6	64·8	73·0	63·3	63·9	54·8	63·9	61·7	+ 0·6	− 19·0	5
7	85·9	46·2	69·3	47·9	59·1	61·7	60·2	− 0·9	− 32·5	6
8	**44·1**	**54·2**	**57·6**	**59·0**	**53·3**	**53·6**	**55·6**	**− 5·5**	**− 37·1**	**7**
9	33·8	54·7	67·9	57·7	53·6	53·5	53·8	− 7·3	− 25·4	8
10	64·1	52·0	51·2	56·9	49·5	54·7	57·7	− 3·4	+ 1·8	9
11	69·6	66·4	76·7	63·2	63·4	67·9	63·9	+ 2·8	+ 30·9	10
12	84·7	56·9	76·5	50·3	57·8	65·2	65·6	+ 4·5	+ 44·8	11
13	79·9	51·5	63·1	63·7	63·9	64·4	—	—	—	—

The minimum rainfall occurs very nearly at the epoch of minimum sunspots, but there are still indications of a double oscillation.

The mean for the cycle is 61·1 inches, and of the rainfall for the whole period 61·5 inches.

40. For Bombay alone we have the following results :—

TABLE XXIV.—Rainfall of Bombay.—Maximum years in 6th line.

Years	1824–36	1832–44	1843–55	1855–67	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.		
1	34·0	74·1	59·3	41·2	52·1	—	—	—	—
2	72·2	71·4	65·4	65·9	68·7	63·3	− 9·0	− 37·2	1
3	78·5	70·5	54·7	51·3	63·7	66·5	− 5·8	− 22·8	2
4	81·0	62·6	73·9	62·4	70·0	73·6	+ 1·3	+ 4·4	3
5	122·0	88·0	76·0	77·2	90·8	79·6	+ 7·3	+ 33·0	4
6	**65·6**	**64·6**	**75·9**	**62·1**	**67·0**	**75·8**	**+ 3·5**	**+ 43·8**	**5**
7	71·9	50·8	114·9	76·9	78·6	74·7	+ 2·4	+ 32·9	6
8	101·8	73·6	50·2	73·6	74·8	76·1	+ 3·8	+ 14·3	7
9	74·1	63·1	91·1	77·7	76·5	73·0	+ 0·7	− 2·9	8
10	71·4	71·5	69·3	45·6	64·4	70·4	− 1·9	− 16·6	9
11	70·5	95·2	62·6	77·8	76·5	72·0	− 0·3	− 24·7	10
12	62·6	59·3	82·1	78·4	70·6	70·4	− 1·9	− 24·0	11
13	88·0	65·4	41·2	62·3	64·2	—	—	—	—

The rainfall is at its maximum about a year before the time of maximum sunspots.

The mean of the cycle is 72·3 inches, and of the rainfall for the forty-four years 71·4 inches.

If the minimum years be placed in the eighth line, it will be found that the minimum rainfall occurs a little after the minimum of sunspots, and that it is *eleven* inches below the mean, but, generally, the variation is rather irregular.

41. The Madras rainfall gives the following results :—

TABLE XXV.—Madras.—Maximum years in 6th line.

Years	1811–23	1824–36	1832–44	1843–55	1855–67	1865–77	Means	Mean Cycle	Variation	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.	in.	in.	
1	—	33·7	18·4	50·3	32·3	41·6	35·3	—	—	—
2	—	56·0	37·1	65·4	47·0	51·4	51·4	45·3	− 3·2	1
3	45·1	60·7	39·0	38·1	52·9	24·4	43·4	48·3	− 0·2	2
4	32·4	88·4	41·5	79·8	48·5	41·4	55·3	51·3	+ 2·8	3
5	56·0	37·9	44·8	81·0	55·1	32·3	51.2	51·2	+ 2·7	4
6	**41·2**	**36·9**	**49·3**	**54·8**	**27·6**	**74·1**	**47·3**	**48·1**	**− 0·4**	**5**
7	63·6	32·4	52·3	39·8	37·2	56·3	46·9	48·7	+ 0·2	6
8	76·2	44·3	53·1	36·9	38·2	73·7	53·7	50·4	+ 1·9	7
9	36·3	18·4	58·6	64·3	54·6	51·8	47·3	51·5	+ 3·0	8
10	70·0	37·1	58·3	72·7	47·2	62·9	58·0	50·7	+ 2·2	9
11	47·1	39·0	36·5	35·8	41·6	37·1	39·5	45·4	− 3·1	10
12	59·6	41·5	50·3	43·2	51·4	21·5	44·6	42·1	− 6·4	11
13	26·6	44·8	65·4	32·3	24·4	45·0	39·7	—	—	—

Here we have evidence of a double oscillation in the rainfall.

The mean of the rainfall from 1813 to 1877, and also for the cycle is 48·5 inches.

As a matter of fact, the Madras rainfall is *below* its mean when the sunspots are at their maximum.

42. The following results are obtained for Madras by the converse arrangement.

TABLE XXVI.—Madras.—Minimum years in 8th line.

Years	1816–28	1826–38	1836–48	1849–61	1860–72	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.	in.		
1	41·2	60·7	44·7	39·8	27·6	42·8	—	—	—	—
2	63·6	88·4	49·3	36·9	37·2	55·1	51·7	+ 2·7	+ 23·3	1
3	76·2	37·9	52·3	64·3	38·2	53·8	52·3	+ 3·3	+ 14·5	2
4	36·3	36·9	53·1	72·7	54·6	50·7	51·0	+ 2·0	+ 4·8	3
5	70·0	32·4	58·6	35·8	47·2	48·8	48·8	− 0·2	− 5·6	4
6	47·1	44·3	58·3	43·2	41·6	46·9	45·5	− 3·5	− 19·0	5
7	59·6	18·4	36·5	32·3	51·4	39·6	40·8	− 8·2	− 32·5	6
8	**26·6**	**37·1**	**50·3**	**47·0**	**24·4**	**37·1**	**40·0**	**− 9·0**	**− 37·1**	**7**
9	33·7	39·0	65·4	52·9	41·4	46·5	43·3	− 5·7	− 25·4	8
10	56·0	41·5	38·0	48·5	32·3	43·4	49·0	0·0	+ 1·8	9
11	60·7	44·8	79·8	55·1	74·1	62·9	57·4	+ 8·4	+ 30·9	10
12	88·4	49·5	81·0	27·6	56·3	60·5	58·8	+ 9·8	+ 44·8	11
13	37·9	52·3	54·8	37·2	73·7	51·2	—	—	—	—

The rainfall is least when the sunspots are fewest, and (apparently) greatest when the spots are most numerous, but this last result probably arises from the maximum years not being all in the same series.

The mean rainfall of the cycle is 49·0 inches, and the mean rainfall from 1816 to 1872 is 49·1 inches.

43. The rainfall of Calcutta, as far as is known, is *greater* in the years of minimum than in those of maximum sunspots.

VII.—Rainfall at Stations in the Southern Hemisphere compared with the Sunspots.

44. The observations obtained from this part of the world are few in number, and the periods also few, but the results, when compared with those of the northern hemisphere, are interesting.

TABLE XXVII.—Rainfall at five stations in the Southern Hemisphere, from 1855 to 1867.—Maximum year in 6th line.

Years	Mauritius	Cape	Adelaide	Melbourne	Sydney	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.	in.		
1855	42·7	24·6	23·1	28·2	52·8	34·3	—	—	—	—
1856	46·2	21·9	24·9	29·7	43·3	33·2	33·5	− 0·1	− 39·2	1
1857	43·4	22·7	21·2	28·9	50·9	33·4	32·3	− 1·3	− 22·7	2
1858	35·3	24·1	21·5	26·0	39·6	29·3	32·3	− 1·3	+ 7·0	3
1859	72·1	36·7	14·8	21·8	42·0	37·5	36·8	+ 3·2	+ 33·5	4
1860	**57·3**	**29·1**	**19·7**	**25·4**	**82·8**	**42·9**	**42·0**	**+ 8·4**	**+ 40·0**	**5**
1861	87·1	25·4	25·1	29·1	58·4	45·0	40·0	+ 6·4	+ 28·4	6
1862	36·0	32·0	22·9	22·1	24·0	27·4	33·6	0·0	+ 11·8	7
1863	42·4	25·6	22·8	36·4	47·1	34·9	32·5	− 1·1	− 0·2	8
1864	30·6	18·9	18·8	27·4	69·1	33·0	31·7	− 1·9	− 7·6	9
1865	56·7	18·7	14·7	15·9	36·3	28·5	26·6	− 7·0	− 17·8	10
1866	25·1	19·2	19·8	22·4	36·8	24·7	27·9	− 5·7	− 32·0	11
1867	42·0	23·0	19·2	25·8	59·7	33·9	—	—	—	—

The rainfall and sunspots are at their maximum about the same time.

The mean rainfall of the cycle is 33·6 inches, and for the years 1855 to 1867 it is 33·7 inches.

45. The next table gives the results obtained by the contrary arrangement. From 1848 to 1860 we have the rainfalls of the Cape, Adelaide, and Sydney; and from 1859 to 1871 the rainfalls of the same three stations, and of Mauritius, Brisbane, and Melbourne.

TABLE XXVIII.—Rainfall at three and six stations in Southern Hemisphere.—Minimum years in 9th line.

Years	1848–60	1859–71	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.		
1	31·3	34·5	32·9	—	—	—	—
2	23·8	42·8	33·3	34·7	+ 2·0	+ 40·5	1
3	32·6	46·1	39·3	34·8	+ 2·1	+ 23·8	2
4	28·7	26·3	27·5	32·3	− 0·4	+ 9·4	3
5	31·4	39·0	35·2	32·6	− 0·1	− 1·9	4
6	31·4	34·2	32·8	31·1	− 1·6	− 12·6	5
7	21·5	25·7	23·6	27·4	− 5·3	− 26·0	6
8	33·5	26 0	29 8	29·2	− 3·5	− 38·5	7
9	**30·0**	**37·4**	**33·7**	**32·4**	**− 0·3**	**− 38·6**	**8**
10	31·6	33·8	32·7	33·0	+ 0·3	− 18·9	9
11	28·4	37·9	33·1	34·4	+ 1·7	+ 16·6	10
12	31·2	45·8	38·5	37·4	+ 4·7	+ 46·1	11
13	43·9	35·5	39·7	—	—	—	—

The minimum rainfall occurs about a year before the epoch of minimum sunspots, and (apparently) the maximum rainfall about the time of maximum sunspots.

The mean for the cycle is 32·7 inches, and for the period 1848 to 1871 it is 32·9 inches.

46. The next two tables are formed by taking Australia alone for single sunspot periods.

TABLE XXIX.—Rainfall at four stations in Australia, from 1865 to 1877.—Maximum year in 6th line.

Years	Brisbane	Melbourne	Adelaide	Sydney	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.		
1865	24·1	15·9	14·7	36·3	22·7	—	—	—	—
1866	51·2	22·4	19·8	36 8	32·5	32·0	− 5·7	− 39·7	1
1867	61·0	25·8	19·2	59 7	41·4	36·0	− 1·7	− 39·9	2
1868	36·0	18·3	18·0	43·1	28·8	33·5	− 4·2	− 16·9	3
1869	54·4	24·6	13·6	48·2	35·2	37·3	− 0·4	+ 24·3	4
1870	**79·1**	**33·8**	**23·9**	**64·2**	**50·2**	**43·3**	**+ 5·6**	**+ 56·9**	**5**
1871	45·4	30·2	23·5	52·3	37·8	40·3	+ 2·6	+ 57·6	6
1872	49·2	32·5	23·2	37·1	35·5	38·6	+ 0·9	+ 38·1	7
1873	62·0	25·6	21·6	73·4	45·6	41·0	+ 3·3	+ 12·4	8
1874	38·7	28·1	19·1	63·6	37·4	41·2	+ 3·5	− 13·9	9
1875	67·0	32·9	31·4	46·2	44·4	39·1	+ 1·4	− 34·1	10
1876	53·4	23·9	13·9	—	30·4	33·0	− 4·7	− 45·0	11
1877	31·2	24·1	24·3	—	26·5	—	—	—	—

Considering the fewness of the observations, and the shortness of the period of observation, the results are rather remarkable. The variation is irregular; yet the maximum and minimum rainfalls occur at or near the epochs of maximum and minimum sunspots.

The mean rainfall for the cycle is 37·7 inches, and for the period 36·0 inches.

47. From the rainfalls at the same stations we get the following results for 1859 to 1871:—

TABLE XXX.—Rainfall at four stations in Australia, from 1859 to 1871.—Minimum year in 9th line.

Years	Brisbane	Melbourne	Adelaide	Sydney	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.		
1859	35·0*	21·8	14·8	42·0	28·4	—	—	—	—
1860	54·6	25·4	19·7	82·8	45·6	41·2	+ 4·9	+ 33·0	1
1861	69·4	29·1	25·1	58·4	45·5	40·2	+ 3·9	+ 21·4	2
1862	28·4	22·1	22·9	24·0	24·3	34·5	− 1 8	+ 4·8	3
1863	68·8	36·4	22·8	47·1	43·8	38·1	+ 1·8	− 7·2	4
1864	47·0	27·4	18·8	69·1	40·6	36·9	+ 0·6	− 14·6	5
1865	24·1	15·9	14·7	36·3	22·7	28·7	− 7·6	− 25·8	6
1866	37·2	22·4	19·8	36·8	29·0	30·5	− 5·8	− 39·0	7
1867	**61·0**	**25·8**	**19·2**	**59·7**	**41·4**	**35·1**	**−1·2**	**− 39·2**	**8**
1868	36·0	18·3	17·9	43·6	28·9	33·6	− 2·7	− 16·2	9
1869	54·4	24·6	13·6	48·2	35·2	37·4	+ 1·1	+ 25·0	10
1870	79·1	33·8	23·9	64·5	50·3	43·4	+ 7·1	+ 57·6	11
1871	45·4	30·2	23·5	52·1	37·8	—	—	—	—

* Interpolated.

The minimum rainfall took place about a year before the minimum sunspots, and the maximum rainfall about the time of maximum sunspots.

The rainfall for the mean cycle is 36·3 inches, and 36·4 inches for the years 1859 to 1871.

48. As an example of the rainfall variation at a single station in the southern hemisphere, we may take the Cape observations. There are only two periods, but the results, as given in the next two tables, are significant.

TABLE XXXI.—Cape of Good Hope (Observatory).—Maximum years in 6th line.

Years	1843–55	1855–67	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.		
1	24·8	24·6	24·7	—	—	—	—
2	18·8	21·9	20·3	21·7	− 2·3	− 39 0	1
3	20·9	22·7	21·8	21·8	− 2·2	− 22·5	2
4	22·5	24·1	23·3	24·4	+ 0 4	+ 4·7	3
5	22·4	36·7	29·5	27·1	+ 3·1	+ 33·5	4
6	**23·2**	**29·1**	**26·1**	**26·6**	**+ 2·6**	**+ 44·5**	**5**
7	24·6	25·4	25·0	27·2	+ 3·2	+ 31·0	6
8	33·5	32·0	32·7	28·3	+ 4·3	+ 12·4	7
9	20·3	25·6	22·9	24·8	+ 0·8	+ 0·4	8
10	23·2	18·9	21·0	21·2	− 2·8	− 8·6	9
11	21·2	18·6	19·9	20 1	− 3·9	− 20·7	10
12	20·0	19·2	19·6	20·7	− 3·3	− 35·7	11
13	24·6	22·9	23·7	—	—	—	—

The mean of the mean cycle is 24·0 inches, and 23·9 inches for the years 1843 to 1867.

49. The converse arrangement gives the following results:—

TABLE XXXII.—Cape of Good Hope (Observatory).—Minimum years in 8th line.

Years	1849–61	1860–72	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.		
1	24·6	29·1	26·8	—	—	—	—
2	33·5	25·4	29·4	27·9	+ 3·3	+ 23·0	1
3	20·3	32·0	26·1	26·5	+ 1·9	+ 8·6	2
4	23·2	25·6	24·4	23·7	− 0·9	− 2·7	3
5	21·2	18·9	20·0	20·9	− 3·7	− 13·4	4
6	20·0	18·7	19·3	20·1	− 4·5	− 26·8	5
7	24·6	19·2	21·9	21·3	− 3·3	− 39·3	6
8	**21·9**	**23·0**	**22·4**	**22·3**	**− 2·3**	**− 39·4**	**7**
9	22·7	22·9	22·8	24·0	− 0·6	− 19·7	8
10	24·1	32·3	28·2	27·9	+ 3·3	+ 15·8	9
11	36·7	28·1	32·4	29·4	+ 4·8	+ 45·3	10
12	29·1	20·1	24·6	27·0	+ 2·4	+ 48·9	11
13	25·4	29·3	27·3	—	—	—	—

The mean of the mean cycle is 24·6 inches, and the mean rainfall, from 1849 to 1872, is 24·9 inches.

In both tables the rainfall and the sunspots are respectively below or above their means in the same years.

VIII.—Combinations of the preceding Results.

50. Combining some of the results now obtained, we get the following table, from which it will be seen that the maximum and minimum rainfalls apparently coincide with the maximum and minimum sunspots respectively.

TABLE XXXIII.—Combination of Tables III., VII., XVIII., XXI., and XXVII.—Maximum years in 6th line.

Years	Great Britain	Contnt. of Europe	America	India	Southern Hemi-sphere	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.	in.		
1	29·1	26·6	41·3	45·3	34·3	35·3	—	—	—	—
2	29·5	26·6	36·5	61·0	33·2	37·4	36·7	− 2·0	− 38·7	1
3	28·8	23·6	41·2	57·9	33·4	37·0	37·8	− 0·9	− 22·8	2
4	31·9	25·7	43·6	68·8	29·3	39·9	39·5	+ 0·8	+ 5·7	3
5	33·2	26·5	41·6	68·4	37·5	41·4	40·6	+ 1·9	+ 33·2	4
6	**32·1**	**29·5**	**41·6**	**53·4**	**42·9**	**39·9**	**40·6**	**+ 1·9**	**+ 41·9**	**5**
7	32·6	25·8	42·4	60·0	45·0	41·2	40·5	+ 1·8	+ 30·5	6
8	34·2	29·4	45·2	62·1	27·4	39·7	39·2	+ 1·1	+ 13·0	7
9	29·7	26·3	41·6	59·4	34·9	38·4	38·9	+ 0·2	+ 1·5	8
10	34·8	26·9	41·2	60·9	33·0	39·4	38·2	− 0·5	− 12·1	9
11	28·2	24·5	41·1	57·2	28·5	35·9	36·9	− 1·8	− 21·2	10
12	31·6	27·4	40·2	58·1	24·7	36·4	36·7	− 2·0	− 28·0	11
13	30·1	29·5	39·5	58·9	33·9	38·4	—	—	—	—

51. All the preceding tables have been formed in the manner described in paragraphs 4, 5, and 7.

52. If it should be said that in the first half of the method the sunspots and the rainfall for the minimum years are too much dispersed, and that in the second half the sunspots and the rainfall for the maximum years are also too much dispersed, the reply would be that the method

gives well-marked sunspot cycles, and that in all the comparisons both the sunspots and the rainfall have been subjected to exactly the same treatment; and it might be added that the amount of dispersion is much less than it would be in a method in which both the maximum and the minimum years were dispersed over more than one half of the common cycle.

53. In order, however, to remove such a possible objection, I will, as, far as possible, compare the rainfall with the sunspots, cycle by cycle, from 1823 to 1867.

TABLE XXXIV.—Comparison of rainfall with sunspots, from 1823 to 1834.—Maximum year (1829) in 7th line.

Years	Great Britain, 10 Stations	Continent of Europe, 4 Stations	America, 2 Stations	India, 2 Stations	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.		
1823	31·1	26·4	49·8	44·1	37·8	—	—	—	—
1824	30.9	27·7	39·0	33·8	32·8	35·0	− 5·0	− 31·4	1
1825	26·6	22·8	33·1	64·1	36·6	36·5	− 3·5	− 21·3	2
1826	23·7	21·4	45·2	69·6	40·0	41·0	+ 1·0	− 5 8	3
1827	29·5	27·0	50·1	84·7	47·8	44·7	+ 4·7	+ 9·7	4
1828	33·0	25·6	34·3	79·9	43·2	43·7	+ 3·7	+ 20·5	5
1829	**28·7**	**29·3**	**53·1**	**51·2**	**40·6**	**40·9**	**+ 0·9**	**+ 25·7**	**6**
1830	30·8	23·0	51·0	52·1	39·2	41·4	+ 1·4	+ 25·0	7
1831	32·3	29·4	52·6	73·0	46·8	41·9	+ 1·9	+ 12·9	8
1832	26·2	22·1	45·2	46·2	34·9	38·5	− 1·5	− 9·8	9
1833	29·7	27·7	38·8	54·2	37·6	36·1	− 3·9	− 25·5	10
1834	24·5	19·9	39·1	54·7	34·5	—	—	—	—

The mean for the cycle is 40·0 inches, and for the whole period (1823 to 1834), the mean is 39·3 inches.

The rainfall reaches its maximum about two years before the year of maximum sunspots, and its minimum at the time of minimum sunspots.

There is, apparently, a tendency to a double oscillation in the rainfall.

The mean cycle corresponds with the years 1824 to 1833.

54. The variation for each country is given in the following table.

TABLE XXXV.—Rainfall variations from 1824 to 1833.

Years of Cycle	Great Britain	Continent of Europe	America	India	Mean Var.	Spot Var.
1	+ 0·8	+ 0·8	− 4·3	− 17·1	− 5·0	− 31·4
2	− 2·1	− 1·7	− 6·9	− 3·1	− 3·5	− 21·3
3	− 3·2	− 2·2	− 1·1	+ 11·0	+ 1·1	− 5·8
4	− 0·1	− 0·1	+ 0·4	+ 18·7	+ 4·7	+ 9·7
5	+ 2·0	+ 1·5	− 1·6	+ 12·9	+ 3·7	+ 20·5
6	+ 1·3	+ 1·5	+ 3·3	− 2·4	+ 0·9	+ 25·7
7	+ 1·6	+ 0·8	+ 7·4	− 3·9	+ 1·5	+ 25·0
8	+ 1·4	+ 0·6	+ 5·8	0·0	+ 1·9	+ 12·9
9	− 0·4	0·0	+ 0·9	− 7·1	− 1·6	− 9·8
10	− 1·5	− 1·0	− 4·1	− 8·7	− 3·8	− 25·5

It will be seen that the variations for Great Britain and the Continent are nearly alike, and that those for America and India show a tendency to a double oscillation.

55. Taking now the sunspot period 1833 to 1844, we get the following table :—

TABLE XXXVI.—Comparison of rainfall with sunspots from 1833 to 1844.—Maximum year (1837) in fifth line.

Years	Great Britain, 18 Stations	Continent of Europe, 19 Stations	America, 10 Stations	India, 3 Stations	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.		
1833	29·4	28·8	39·6	56·4	38·5	—	—	—	—
1834	25·8	22·0	35·3	59·3	35·6	36·9	− 1·9	− 35·6	1
1835	29·0	24·1	36·7	63·2	38·2	38·0	− 0·8	+ 3·3	2
1836	34·2	27·6	39·1	59·4	40·1	38·5	− 0·3	+ 49·1	3
1837	**26·2**	**28·7**	**35·4**	**52·5**	**35·7**	**36·9**	**− 1·9**	**+ 64·7**	**4**
1838	28·4	27·8	37·3	52·0	36·4	37·3	− 1·5	+ 47·6	5
1839	32·1	30·7	37·2	63·9	41·0	39·2	+ 0·4	+ 23·8	6
1840	25·3	27·9	40·2	60·4	38·4	40·0	+ 1·2	+ 2·0	7
1841	34·1	28·5	43·8	63·3	42·4	40·9	+ 2·1	− 18·9	8
1842	24·9	26·1	41·5	69·3	40·4	40·8	+ 2·0	− 34·9	9
1843	29·7	30·3	42·5	57·6	40·0	40·0	+ 1·2	− 42·2	10
1844	24·3	30·5	36·2	68·2	39·8	—	—	—	—

The years of the mean cycle are 1834 to 1843.

The mean rainfall for the cycle is 38·8 inches, and for the years 1833 to 1844 it is 38·9 inches.

The rain increases from the first to the third year of the cycle, but in the fourth decreases, rising again till the eighth year, and then falling to the tenth. This indicates a double oscillation, as in Table XXXIV.

The general results of the comparison, however, are unfavourable, the maximum rainfall coinciding nearly with the minimum sunspots in the ninth year, and the minimum rainfall with the maximum sunspots in the fourth year of the cycle.

It will be seen by inspecting the columns for the mean rainfalls of the several countries that these unsatisfactory results are mainly due to the rainfalls of America and India, which are represented by ten and three stations respectively.

56. Taking Great Britain and the Continent of Europe alone, the results as given in next table are obtained.

The mean for the cycle and also for the years 1833 to 1844 is 28·2 inches.

The maximum rainfall occurs two years after the year of maximum sunspot.

The minimum rainfall occurs, first, in the year of minimum sunspot at the commencement of the cycle, and, again, nearly in the year of minimum sunspot at the end of the cycle.

There is a tendency to a small second minimum about the time of maximum sunspot.

TABLE XXXVII.—Comparison of the Rainfall of Europe with the sun-spots from 1833 to 1844.—Maximum year (1837) in 5th line.

Years	Mean Rainfall	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.		
1833	29·1	—	—	—	—
1834	23·9	25·8	– 2·4	– 35·6	1
1835	26·5	26·9	– 1·3	+ 3·3	2
1836	30·9	28·9	+ 0·7	+ 49·1	3
1837	**27·4**	**28·4**	**+ 0·2**	**+ 64·7**	**4**
1838	28·1	28·7	+ 0·5	+ 47·6	5
1839	31·4	29·3	+ 1·1	+ 23·8	6
1840	26·6	28·9	+ 0·7	+ 2·0	7
1841	31·3	28·6	+ 0·4	– 18·9	8
1842	25·5	28·0	– 0·2	– 34·9	9
1843	30·0	28·2	0·0	– 42·2	10
1844	27·4	—	—	—	—

As these results, derived from the rainfalls at thirty-seven stations are decidedly favourable, the results in Table XXXVI. must be regarded as only partially unfavourable.

57. For the next sunspot cycle we get the following results :—

TABLE XXXVIII.—Comparison of rainfall with sunspots from 1843 to 1857.—Maximum year (1848) in 6th line.

Years	Great Britain, 31 Stations	Continent of Europe, 20 Stations	America, 28 Stations	India, 3 Stations	Southern Hemisphere, 2 Stations	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.	in.		
1843	31·8	29·1	42·9	57·6	21·0	36·5	—	—	—	—
1844	26·9	30·0	37·4	68·2	17·8	36·1	35·8	– 1·8	– 31·0	1
1845	33·3	31·3	38·2	51·2	19·9	34·8	36·8	– 0·8	– 14·7	2
1846	35·1	29·8	41·5	76·7	24·7	41·6	39·6	+ 2·0	+ 10·2	3
1847	28·6	26·7	45·5	76·5	25·0	40·5	40·2	+ 2·6	+ 41·3	4
1848	**37·3**	**30·5**	**40·0**	**63·1**	**21·5**	**38·5**	**39·2**	**+ 1·6**	**+ 57·1**	**5**
1849	30·6	27·2	39·0	75·1	25·0	39·4	38·7	+ 1·1	+ 42·8	6
1850	29·9	31·2	46·5	54·5	26·4	37·7	38·4	+ 0·8	+ 21·0	7
1851	29·3	30·6	36·7	73·2	25·5	39·1	39·4	+ 1·8	+ 8·7	8
1852	39·0	28·2	43·1	74·5	25·3	42 0	39·5	+ 1·9	– 1·8	9
1853	30·9	29·6	39·9	50·2	24·1	34·9	36·7	– 0·9	– 15·9	10
1854	28·4	27·0	38·9	63·9	17·7	35·2	34·7	– 2·9	– 31·5	11
1855	25·5	30·7	41·1	47·9	23·9	33·8	34·6	– 3·0	– 43·2	12
1856	31·4	29·0	35·4	59·0	23·4	35·6	34·9	– 2·7	– 43·3	13
1857	29·3	22·5	42·3	57·7	21·9	34·7	—	—	—	—

For the above period (1843-57) we have two stations in the southern hemisphere, namely, the Cape and Adelaide. The Melbourne and Sydney observations cannot be used, because in the former there is a blank for the years 1851 to 1854, and because the latter were not commenced till 1856, the observations previously to that year having been made at South Head.

The mean for the cycle is 37·6 inches, and 37·4 inches for the years 1843 to 1857.

The maximum rainfall occurs about one year before the year of maximum sunspots, and the minimum rainfall in the years of minimum sunspots at the beginning and end of the cycle.

There is apparently a tendency to a double oscillation, the rainfall diminishing a little from the fourth to the seventh year of the cycle, and then increasing a little to the ninth year.

58. The following table shows the variation for each country or district.

TABLE XXXIX.—Rainfall variations from 1844 to 1856.

Years of Cycle	Great Britain	Continent of Europe	America	India	Southern Hemisphere.	Mean Var.	Spot Var.
	in.	in.	in.	in.	in.	in.	
1	− 1 6	+ 0·9	− 1·5	− 2·6	− 4·0	− 1·8	− 31·0
2	+ 0·8	+ 1·4	− 1·6	− 2·1	− 2·6	− 0·8	− 14·7
3	+ 1·7	+ 0·2	+ 1·2	+ 6·3	+ 0·4	+ 2·0	+ 10·2
4	+ 1·1	− 0 8	+ 2·7	+ 9·3	+ 0·9	+ 2·6	+ 41·3
5	+ 2·1	− 0·5	+ 0·7	+ 5·5	+ 0·1	+ 1·6	+ 57·1
6	+ 0 8	− 0·2	+ 0·7	+ 3·0	+ 1·3	+ 1·1	+ 42·8
7	− 1·4	+ 0·8	+ 1·7	+ 0·4	+ 2 7	+ 0·8	+ 21·0
8	+ 0·5	+ 0·9	+ 0·3	+ 4·9	+ 2·5	+ 1·8	+ 8·7
9	+ 3·2	− 0·1	+ 0·3	+ 4·2	+ 1·9	+ 1·9	− 1·8
10	+ 1·0	− 0·6	0·9	− 4 2	− 0·3	− 0·8	− 15·9
11	− 3·0	− 0·7	− 0·7	− 7·5	− 2·3	− 2·8	− 31·5
12	− 3·6	+ 0·1	− 1·3	− 9·3	− 0·9	− 3·0	− 43·2
13	− 1·9	− 1·4	− 2·9	− 8·0	0·0	− 2·7	− 43·3

In Great Britain the maximum and minimum rainfalls are respectively in or very near the years of maximum and minimum sunspots, but there seems to be a tendency to a double oscillation.

The variation for the Continent of Europe is, on the whole, unfavourable. This arises from heavy rains having occurred at a good many stations in 1844 and 1845.

Both in America and in India the maximum rainfall occurs one year before the year of maximum sunspots, and the minimum rainfall in the years of minimum sunspots, with, however, a tendency to a second minimum and maximum between the principal maximum and minimum.

The variation of the mean rainfall of the two stations in the southern hemisphere is similar to the variations of the rainfalls of Great Britain, America, and India.

59. Coming now to the next sunspot cycle, 1856 to 1867, we get the results as given in Table XL.

Not having the rainfalls of the ten American stations for 1868, I have taken the thirteen years 1855–67 instead of the years 1856–68.

The mean rainfall for the cycle is 38·4 inches, and 38·5 inches for the years 1855–67.

The years of maximum and minimum rainfall coincide with the years of maximum and minimum sunspots, except in the eleventh year of the cycle, and there is little or no appearance of a double oscillation.

TABLE XL.—Comparison of Rainfall with Sunspots from 1855 to 1867.—Maximum year in 6th line.

Years	Great Britain, 30 Stations	Continent of Europe, 30 Stations	America, 10 Stations	India, 4 Stations	Southern Hemisphere, 5 Stations	Means	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.	in.		
1855	27·1	27·2	42·4	42·0	34·3	34·6	—	—	—	—
1856	35·0	25·1	35·6	55·4	33·2	36·9	36·2	− 2·2	− 39·7	1
1857	32·5	19·7	46·0	51·7	33·4	36·7	36·6	− 1·8	− 39·9	2
1858	34·1	22·1	46·0	50·6	29·3	36·4	37·6	− 0·8	− 16·9	3
1859	37·0	26·1	47·7	57·6	37·5	41·2	39·3	+ 0·9	+ 24·3	4
1860	**36·1**	**29·4**	**37·8**	**46·7**	**42·9**	**38·6**	**40·3**	+ **1·9**	+ **56·9**	**5**
1861	40·7	25·1	42·4	61·0	45·0	42·8	40·9	+ 2·5	+ 57·6	6
1862	42·7	26·3	44·4	57·1	27·4	39·6	40·4	+ 2·0	+ 38·1	7
1863	38·2	24·5	44·3	57·7	34·9	39·9	39·0	+ 0·6	+ 12·4	8
1864	36·1	23·4	39·2	51·5	33·0	36·6	37·4	− 1·0	− 13·9	9
1865	32·5	22·5	44·0	54·8	28·5	36·5	36·9	− 1·5	− 34·1	10
1866	40·0	27·1	40·7	59·1	24·7	38·3	38·1	− 0·3	− 45·0	11
1867	37·1	29·2	42·8	53·3	33·9	39·3	—	—	—	—

60. The variations for the several countries are as follows:—

TABLE XLI.—Rainfall Variations from 1855 to 1867.

Years of Cycle	Great Britain	Cont. of Europe	America	India	Southern Hemisphere	Mean Variation	Spot Variation
	in.	in.	in.	in.	in.	in.	
1	− 4·1	− 0·5	− 2·8	− 3·3	− 0·3	− 2·2	− 39·7
2	− 3·0	− 3·1	+ 0·7	− 2·1	− 1·5	− 1·8	− 39·9
3	− 2·1	− 2·2	+ 3·7	− 1·8	− 1·5	− 0·8	− 16·9
4	− 0·5	+ 1·2	+ 2·1	− 1·3	+ 3·0	+ 0·9	+ 24·3
5	+ 0·9	+ 2·8	− 1·3	− 1·4	+ 8·2	+ 1·9	+ 56·9
6	+ 3·5	+ 1·7	− 1·0	+ 2·0	+ 6·2	+ 2·5	+ 57·6
7	+ 4·5	+ 0·8	+ 1·1	+ 3·8	− 0·2	+ 2·0	+ 38·1
8	+ 2·3	− 0·1	+ 0·3	+ 1·6	− 1·3	+ 0·6	+ 12·4
9	− 0·8	− 1·2	− 1·1	− 0·6	− 1·5	+ 1·0	− 13·9
10	− 1·3	− 0·9	− 0·8	+ 0·6	− 5·2	− 1·5	− 34·1
11	+ 0·9	+ 1·7	− 0·7	+ 2·1	− 5·9	− 0·4	− 45·0

In Great Britain the rainfall increases to the seventh year of the cycle and on the Continent to the fifth year, after which it decreases to the tenth and ninth years, and then increases in the eleventh.

The rainfall at the American stations has, apparently, a tendency to a double oscillation.

At the Indian stations the rainfall increases to the seventh year as in Great Britain. It then decreases to the ninth year, but increases in the tenth and eleventh years.

The mean rainfall of the five stations in the southern hemisphere increases from the second to the fifth year, and then decreases to the eleventh, and the maximum and minimum rainfall occur in or very near the years of maximum and minimum sunspots.

61. Omitting the stations in the southern hemisphere, the mean variation for Europe, America, and India is given in column one of the

following table; in column two the mean variation for Europe and America is given; and in column three the variation for Europe alone is given.

1	2	3	Spot Var.	Years of Cycle
Rain Var.	Rain Var.	Rain Var.		
in.	in.	in.		
− 2·7	− 2·5	− 2·3	− 39·7	1
− 1·3	− 1·8	− 3·0	− 39·9	2
− 0·6	− 0·1	− 2·1	− 16·9	3
+ 0·4	+ 0·9	+ 0·3	+ 24·3	4
+ 0·2	+ 0·8	+ 1·8	+ 56·9	5
+ 1·5	+ 1·4	+ 2·6	+ 57·6	6
+ 2·5	+ 2·1	+ 2·6	+ 38·1	7
+ 1·0	+ 0·8	+ 1·1	+ 12·4	8
− 0·9	− 1·0	− 1·0	− 13·9	9
− 0·6	− 1·0	− 1·1	− 34·1	10
+ 1·0	+ 0·6	+ 1·3	− 45·0	11

Each of these variations shows that the sunspots and rainfall were below or above their means in the same years, except the eleventh. This exception is owing to heavy rains at some stations in Great Britain in 1866, on the Continent in 1867, and at Bombay in 1865 and 1866.

On the other hand, the rainfall at the stations in the southern hemisphere was greatly below the average in 1865–66–67. Hence the mean rainfall variation for all the stations (Table XL.) is a closer approximation to the sunspot variation than the variations in the above table.

62. The seventy-nine stations in Table XL. include almost all the principal observatories in the world. If we take the latter alone, we get the following results:—

TABLE XLII.—Rainfall at forty Observatories from 1855 to 1867.

Years.	Mean Rainfall	Mean Cycle	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.		
1855	29·2	—	—	—	—
1856	29·2	28·3	− 0·5	− 39·7	1
1857	25·7	26·7	− 2·1	− 39·9	2
1858	26·2	27·2	− 1·6	− 16·9	3
1859	30·7	29·9	+ 1·1	+ 24·3	4
1860	32·0	31·4	+ 2·6	+ 56·9	5
1861	31·1	30·9	+ 2·1	+ 57·6	6
1862	29·7	29·9	+ 1·1	+ 38·1	7
1863	29·4	28·8	0·0	+ 12·4	8
1864	26·9	27·5	− 1·3	− 13·9	9
1865	26·8	27·3	− 1·5	− 34·1	10
1866	29·0	28·7	− 0·1	− 45·0	11
1867	30·2	—	—	—	—

63. Taking only ten observatories, as widely separated as possible, the results as given in next table are obtained.

64. The comparisons which have now been made between the rainfall and the sunspots for *each* of the four cycles from 1824 to 1867 are not liable to any objection that may be founded on the plea of a dispersion of

the years of maximum and minimum in the previous comparisons, and yet the results are similar. It may be urged, however, that the "mean cycle" is formed by "bloxaming" the "means." But this objection,

TABLE XLIII.—Rainfall at ten Observatories from 1855 to 1867.

Years	St. Petersburg	Edinburgh	Paris	Palermo	New Bedford, U.S.	Cambridge, Harvard, U.S.	Bombay	Mauritius	Cape	Melbourne	Means	Mean Cycle	Rain Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	
1855	15·2	20·3	13·5	25·4	36·4	47·6	41·2	42·6	24·6	28·2	29·5	—	—	—
1856	12·2	28·5	22·3	27·2	33·0	53·8	65·9	46·2	21·9	29·7	34·1	32·5	− 2.0	1
1857	12·6	24·9	19·4	26·6	38·6	57·9	51·3	43·4	22·7	28·9	32·6	32·7	− 1·8	2
1858	11·8	24·3	18·3	24·8	42·4	45·4	62·4	35·3	24·1	26·0	31·5	34·0	− 0·5	3
1859	15·8	25·9	21·5	28·3	48·9	59·3	77·2	72·1	36·7	21·8	40·7	37·0	+ 2·5	4
1860	15·3	33·4	25·8	19·4	38·3	45·1	62·1	57·2	29·1	25·4	35·1	37·7	+ 3·2	5
1861	18·0	28·6	18·0	22·5	44·7	50·3	76·9	87·1	25·4	29·1	40·1	37·6	+ 3·1	6
1862	13·5	33·9	20·3	21·6	41·4	57·2	73·6	36·0	32·0	22·1	35·2	36·7	+ 2·2	7
1863	16·6	25·6	16·8	23·4	44·4	56·4	77·7	42·4	25·6	36·4	36·5	34·2	− 0·3	8
1864	20·7	28·1	14·4	24·1	39·5	39·4	45·6	30·6	18·9	27·4	28·9	32·2	− 2·3	9
1865	18·3	23·6	21·4	26·1	44·6	43·6	77·8	56·7	18·6	15·9	34·7	32·3	− 2·2	10
1866	26·4	27·2	25·4	12·2	38·5*	35·5*	78·4	25·1	19·2	22·4	31·0	32·5	− 2·0	11
1867	25·2	31·0	22·2	17·0	45·6	41·7	62·3	42·0	22·9	25·8	33·6	—	—	—

* Interpolations.

also, if it is one, may be removed by making a direct comparison. Taking the thirteen "means" given in Tables III., VII., XVIII., XXI., and XXVII., we get the following results:—

TABLE XLIV.—Direct Comparison of the Rainfall with the Sunspots.—Maximum years in 6th line.

Years	Great Britain 1824–67	Cont. of Europe 1824–67	America, 1824–67	India, 1824–67	S. Hemisphere, 1855–67	Means	Rain Var.	Spot Var.	Years of Cycle
	in.	in.	in.	in.	in.	in.	in.		
1	29·1	26·6	41·3	45·3	34·3	35·3	− 3·2	− 35·1	—
2	29·5	26·6	36·5	61·0	33·2	37·4	− 1·1	− 37·1	1
3	28·8	23·6	41·2	57·9	33·4	37·0	− 1·5	− 21·6	2
4	31·9	25·7	43·6	68·8	29·3	39·9	+ 1·4	+ 8·3	3
5	33·2	26·5	41·6	68·4	37·5	41·4	+ 2·9	+ 43·8	4
6	**32·1**	**29·5**	**41·6**	**53·4**	**42·9**	**39·9**	**+ 1·4**	**+ 55·6**	**5**
7	32·6	25·8	42·4	60·0	45·0	41·2	+ 2·7	+ 36·3	6
8	34·2	29·4	45·2	62·1	27·4	39·7	+ 1·2	+ 18·8	7
9	29·7	26·3	41·6	59·4	34·9	38·4	− 0·1	+ 0·3	8
10	34·8	26·9	41·2	60·9	33·0	39·4	+ 0·9	− 9·9	9
11	28·2	24·5	41·1	57·2	28·5	35·9	− 2·6	− 20·6	10
12	31·6	27·4	40·2	58·1	24·7	36·4	− 2·1	− 23·6	11
13	30·1	29·5	39·5	58·9	33·9	38·4	− 0·1	− 15·3	—

The mean rainfall is 38·5 inches, and the mean of the sunspot numbers is 48·1. Now, the rainfall and the sunspots are below or above their respective

means almost in the same years of the common period, and the epochs of maximum and minimum sunspots coincide nearly with the epochs of minimum and maximum rainfall.

IX.—Summary of Results.

65. If we knew exactly the annual rainfall for the whole globe during the four sunspot periods 1824–67, and found that it varied as the sun's spotted area varied, we should conclude that there was very strong evidence of a causal connection between the two phenomena, especially when it was considered that the comparative frequence or absence of solar spots, faculæ, and prominences indicated a variation in the sun's radiant energy, upon which the variations in terrestrial meteorology mainly depend. But as we do not know the total annual rainfall over the whole surface of the earth, and have only approximate values of the annual amounts of solar maculation, all that can be done is to compare the rainfall at the greatest possible number of stations in different parts of the world with the available values of the sunspot areas, and see whether there is anything approaching to a correspondence. This has been done in the preceding pages, chiefly for the years 1824–67, and the principal results may be summarised as follows :—

(1.) The mean rainfalls of Great Britain, the Continent of Europe, America, and India, as represented by all the returns that have been received, have, notwithstanding some anomalies, varied as Wolf's sunspot numbers have varied, and the epochs of minimum and maximum rainfall have nearly coincided with those of the sunspots.

(2.) The rainfall at five stations in the southern hemisphere for shorter periods give similar results.

(3.) The levels of the principal rivers of Central Europe have also varied with the sunspots, although, as in the case of the rainfall, there are discrepancies.

(4.) The rainfalls at individual stations, such as Edinburgh, Paris, New Bedford, Bombay, &c., afford unmistakable evidence of a connection between sunspots and rainfall.

(5.) The variations in the levels of individual rivers of Central Europe, such as the Rhine and Elbe, give similar evidence.

(6.) The results obtained by taking each sunspot cycle separately are all favourable, with the exception of those for the cycle 1834–43, which are unfavourable for ten stations in America and three stations in India, but favourable for thirty-seven stations in Europe.

(7.) When the final results for each country are combined, by taking means of all of them (Table XXXIII.), it is found that the rainfall and the sunspots are below or above their respective means in the same years, and that the epochs of maximum and minimum rainfall apparently coincide with the epochs of maximum and minimum sunspots.

(8.) The mean range of rainfall variation for the four cycles from 1824 to 1867, taking all the stations, is about 4 inches, and the annual mean rainfall 38·5 inches.

(9.) There is a tendency to a double oscillation in the rainfall, a small second maximum and minimum occurring after the principal maximum. This is especially the case in India.

(10.) The principal maximum and minimum epochs of the rainfall do not occur at the same time in different countries, but oscillate to the

extent of a year or two on either side of the sunspot epochs. On an average, however, the rainfall epochs occur somewhat later than the sunspot epochs.

66. The rainfall and sunspot observations being themselves probably but rough approximations, the evidence of a connection between them is necessarily qualitative rather than quantitative. But, considering how apparently capricious an element the rainfall is, it is difficult to account for the results which have been obtained for widely distant countries and under all conditions of climate, except upon the supposition that they are the manifestations of a general law. The number of rainfall returns is no doubt small, but it is to be remembered that they are all that are available, that they are not a selection, and that virtually they have been obtained by haphazard. Moreover, the experience of seven years has shown that as the number of rainfall returns increased, so did the evidence of a connection between sunspots and rainfall.

67. The present discussion has been almost exclusively confined to the four cycles from 1824 to 1867, because it is supposed that the sunspot observations for those years are superior to earlier observations. But it must be remarked that exactly similar results have been obtained for previous cycles. The rainfall variations for the cycle 1811–23 show a most marked coincidence with the sunspot variations, and similar rainfall results have been obtained for still earlier cycles. Further, the variations in the levels of the Elbe from 1728 to 1868, and in those of the Rhine from 1770 to 1835 were as favourable in the last century as they have been in the present. The cycle 1868–78 is not yet complete, but judging from the rainfalls in 1870–73, and from the droughts which have occurred since 1875, it is not improbable that the general results will be the same as for previous cycles. We know already that the mean rainfall at six stations in the southern hemisphere from 1865 to 1877 is favourable.

Report on Observations of Luminous Meteors during the Year 1877–78, *by a Committee consisting of* James Glaisher, *F.R.S., &c.*, R. P. Greg, *F.G.S., F.R.A.S.*, C. Brooke, *F.R.S.*, Prof. G. Forbes, *F.R.S.E.*, Walter Flight, *D.Sc., F.G.S., and* Prof. A. S. Herschel, *M.A., F.R.A.S.*, (*Reporter*).

The meteoric events of the greatest interest during the past year, of which, as far as space will permit, the principal characters are described in this Report, consist in part of the successive appearances of a rather unusual number of very grand and remarkable fireballs which have been seen in different parts of England, Scotland, and Ireland, and which have been very satisfactorily recorded in those countries; and in part also of some new observations of meteor showers, and of some falls of aërolites, which have added to the increasing store of knowledge of the nature and distribution of those astronomical phenomena which we possess.

A stonefall of considerable abundance and importance took place on the 13th of October, 1877, at Soko-Banja, N.E. of Alexinatz, the circum-

stances of which, as far as they are yet known and investigated, will be found described in the Appendix treating of Äërolites and of the progress of recent researches on them, at the end of the Report. Of similar events and of large fireballs observed in foreign countries, the Committee has also to record some other announcements which it has received. A detonating meteor of unusual magnitude made its appearance in the United States on the afternoon of November 20th, 1877, and was one of unusual grandeur. As it was visible at Richmond and at towns of Virginia and North Carolina, where it exploded, all of them near the capital, and was also seen by many persons in Washington itself, the inquiry undertaken by Professor J. L. Campbell, of the Washington and Lee University, regarding all the special characters of the great Virginia meteor already in part successfully accomplished will, without doubt, contribute some important additions to this department of our meteoric knowledge.

A fireball of the same description, scarcely less imposing, appeared (a few days after the former one) in England on the evening of the 23rd of November last, and was carefully described by a multitude of accounts of it which were preserved, and which were communicated to Captain Tupman. It appears to have been a member of a very well-known meteor shower, whose shooting stars have often afforded plentiful and pretty striking exhibitions in November, with a definite centre of divergence in the head of Taurus. The "Taurids I.," as they have been called, were very abundant in November, 1876, amounting to bright showers, especially on the morning of November 20th in that year; but they were remarkable by a nearly total cessation of the stream last year in the month when this great fireball appeared to compensate, apparently, for the absence of the lesser meteors of the shower. It is premature, until future cases of a similar kind corroborate such a conclusion, to infer that aërolitic meteors are sometimes furnished by ordinary star-showers, since radiant points of very different and independent meteor systems are sometimes found to be closely adjacent to each other; but the evidence thus presented of such a connection existing between a meteor shower and an aërolitic fireball certainly demands close attention and investigation, by the certain determination which was made last year of an almost exact resemblance between two such foreign visitants in the positions of their radiant points.

The orbit of a certain comet, it may be noticed (that of 1702), coincides, as far as the rough observations of it that were obtained will perhaps allow us to conclude, with the date and position of this double meteor radiant-point; and not less likelihood exists that the comet and the two kinds of meteor-bodies formed members together of a common system coursing round the sun, than that the aërolitic meteor itself was only a very large individual of the meteor shower. Captain Tupman has computed, on the other hand, the orbit of a smaller fireball which he saw on the night of the 27th of November, 1877; and this meteor, he discovered, had a nearly circular orbit, slightly inclined to the earth's, which it was overtaking with a periodic time of revolution round the sun of only about 462 days. A large fireball was seen in full sunlight on the forenoon of March 25th, 1878, travelling over the North Sea from the neighbourhood of Berwick to that of Aberdeen. Its height and real path were very well determined, and this large fireball appears to have been directed in its real orbit very nearly straight from the sun towards the earth. The next

large meteor seen shot from over the north of Yorkshire to the Firth of Forth, where it disappeared at a height of 15 or 20 miles very nearly over Edinburgh, on the evening of May 12th, 1878. A report like thunder heard at Galashiels, seems to have resulted from a division of the fireball, seen at Scarborough, by a fragment falling from it some time before the end of its course, when it must have been passing over Galashiels at a distance of about 35 or 40 miles. It belonged to a radiant point in Virgo, very probably identical with that of a new and rich shower of April and May shooting stars, seen by Mr. Denning (and perhaps also, on April 18, 1841, by Professer Forshey, in America) at about 205°–10°, in 1877.

A fireball descended with a detonation to a low height over a point near Market Harborough, on April 2nd, 1878. It was well observed at two places, and its radiant-point in Ursa Major was very well determined. A large fireball which passed slowly over Devonshire on the 7th of June, from the English to the Bristol Channel, probably had the same radiant point, with one or two companion fireballs on the same evening, as the detonating meteor (investigated by Professors Galle and Von Niessl) of June 17th, 1873, in Austria and Bohemia. Of this fireball and of one seen on the night of July 29th over the neighbourhood of Manchester, however, the heights, real courses, and velocities have only been very partially established from the observations.

Among the chief annual meteor showers observed during the past year, all but the April Lyrids were pretty notable displays, denoting well-marked returns of the several special star-showers of the year. The August display of Perseids, in the year 1877, was as bright as, or perhaps a little brighter than the average; but not much more so (if even quite so bright as usual) in August, 1878, the state of the sky at some places being, on August 10th, in both years, very fairly favourable for the observations. The Orionids were well seen, and reached a maximum of 22 meteors per hour on the morning of October 18th, 1877; the meteors were bright, leaving very characteristic streaks, and radiated very exactly from the point near ν Orionis, which is the usual centre of the shower. The Leonids were re-observed in England and in America, where two observers counted thirty of them per hour on the morning of November 14th. The Andromedes were seen both on November 25th and 27th, about as numerous as the unconformable meteors on those nights. The Geminids appeared in greater numbers than usual, reaching a maximum on December 11th, 1877, which was well seen, and the characters and radiant point of the shower were last year very well observed. The meteors of January 2nd also made their appearance in a pretty bright stream, seen in England to be very active on the morning of that day, and affording a pretty good new determination of its radiant-point. Among these regular returns of special showers, the display of the Lyrids of April 19th–21st, in the year 1878, was, on the other hand, somewhat scanty, and inferior to those of the other showers; only a few of its meteors being noticed, and those on the nights of the 21st and 22nd of April, principally, when the meteor shower of the Lyrids ordinarily is well-nigh extinguished.

Throughout the autumn months, in the spring, and again on the approach of the August meteors, Mr. W. F. Denning recorded appearances of meteor showers in watchful observations of the sky whenever the absence of the moon and freedom from clouds offered opportunities for their detection. Of such showers, many were new, and presented other features

of especial interest. A selection of the brightest and most important examples of these new views of meteor systems obtained by Mr. Denning during the past year is included in the third Appendix, following the above notices of the greater annual showers, with extracts from his list of the almost innumerable shower centres of which he succeeded in tracing and recording the existence. From the meteor lists of foreign observers, also, Mr. Denning deduced a vast number of meteor showers, and he has published a list of them in conjunction with that of his own observations. In these two parallel lists the agreements are often very satisfactory and close. Mr. Greg has prepared a valuable abstract of them, showing the many points in which these new results confirm and verify the results of older observations. A similar abstract by Mr. Greg of the extensive shower-catalogue contained in the late Professor Heis' forty-three-year summary of his meteor observations, which was published last year, accompanies the former abstract; and to these lists is added, in the same part of this Report, the well-known catalogue of meteor showers deduced by Professor Schiaparelli from Zezioli's observations of shooting-stars at Bergamo in the years 1867–69, of which no perfect transcript has hitherto appeared in these Reports.

The fourth and last Appendix of the Report describes, as in former years, the occurrences of stone-falls which have taken place, and the results of researches on aërolites and meteoric irons which have been published during the past year; and it will be seen from its perusal that the study of the nature of the substances, and of the circumstances of the falls of aërolites, is being pursued with the same activity and success as has characterised during the past year the observation of shooting-stars and fireballs.

It now begins to appear extremely probable, especially from the results of Mr. Denning's recent observations and reductions, that the highest attainable accuracy in mapping the observed directions of the apparent paths of shooting-stars is the real key to the solution of the problem presented by their nightly flights. Numbers of co-existing radiant-points, which would have escaped detection by less careful observations, are thus shown to be capable of recognition, and of being disentangled from each other with precision. The question of the possible connection of large fireballs, and among them of aërolites, or large stony masses, with such showers, and accordingly, it may be, in certain cases with comets, depends also for its solution upon accurate observations of these meteors. In all the aspects which they present in appearance or position, whether on a large scale of grandeur, or as the smallest scintillations, these singular bodies are certainly attractive objects for accurate investigation and description from the profound obscurity in which at present the whole of the history of their origin appears to be involved. The Committee has thought it desirable, from these considerations, to offer some suggestions to observers, taking the form of general directions for recording exactly any particulars of the occurrences of shooting-stars, fireballs, and aërolites, of which circumstances may enable them to furnish perfectly definite and reliable accounts. The different heads and paragraphs of these directions are added in a convenient series of sections at the end of the Report.

A LIST OF DOUBLE OBSERVATIONS OF SHOOTING-STARS RECORDED IN ENGLAND DURING THE YEARS 1876–77.

Date.	Hour (Approx. G. M. T.)	Place of Observation	Apparent Size, as per Stars or Planets	Colour	Duration, Secs.	Apparent Path, from α δ to α δ	[Projected Radiant Point] α δ	Observer, and Remarks
	h m					° ° ° °	° °	
1876. June 10	About 10 40 p.m.	London.	Small, but bright and dazzling.	A beautiful blue	Motion rather swift.	In the W., moving from N. to W. between Leo Minor and Leo Major.	....	First noticed by its light, while observing ϵ Boötis; passed behind some trees; left no train. — Frank Dennett ('English Mechanic,' vol. xxiii. p. 404, 1876, June 30.)
10	10 44 p.m.	Writtle, near Chelmsford Essex.	= ♃	Green	5 sec ...	In Leo, between γ and δ Leonis (?), Path, 15°	....	Directed from ι or θ Ursæ Majoris. Position imperfectly recorded; left a short streak. —H. Corder.
1877. Aug. 7	10 54 p.m.	Bristol.........	= ♃	Yellow ...	0·7 sec ...	346 + 22 329 − 1 ...	[Adopted Radiant point about 55 + 55.]	Path, 28°; left a streak; Perseïd.—W. F. Denning.
7	10 55 p.m.	Radcliffe. Observatory, Oxford.	= ♀	Red	1·0 sec.	From Vulpecula to Sagittarius. [About 300 + 17 to 283 − 11]		Left a long train.—J. Lucas.
7	11 43 p.m.	Bristol.........	3rd............	White	Rapid, 0·3 secs.	19 + 12 15 + 3	[Near α Lyncis; 95 + 62]	Path, 10°; Radiant γ Andromedæ.—W. F. Denning.
7	11 45 p.m.	Radcliffe Observatory, Oxford.	3rd............	....	Rapid ...	γ Pegasi to Saturn, (351 − 6)	....	J. Lucas.
10	10 25 p.m.	Birmingham.	= ♃	Pale green	1·5 sec. ...	γ or ζ Ursæ Minoris to near χ Boötis, (227 + 29)	[Near θ Persei; 41 + 51.]	Left a streak 30° long.—W. H. Wood.
10	10 26 p.m.	Bristol.........	= ♀	....	0·4 sec ...	77 + 71 142 + 71 (Position accurate)		Path, 21°; flashed like lightning; left a streak for 30 s.—W. F. Denning.
10	10 45 p.m.	Ibid............	1st............	....	Rapid 0·4 sec.	129 + 70 153 + 62	[F Camelopardi; 52 + 64.]	Path, 12°; Perseid.—W. F. Denning.
10	10 45 p.m.	Birmingham.	1st............	Green	0.5 sec. ...	κ Draconis to ζ Ursæ Majoris.	... .	Left a streak; Perseïd.—W. H. Wood.

10	11 5 p.m.	Ibid	4th	Blue	0·5 sec.	97° + 68° (Beginning)	[Near δ Draconis; 284 + 65.]	Path 5°; directed from Polaris. W. H. Wood.
10	11 5 p.m.	York	2nd		0·25 sec.	230 + 73 218 + 72		Path 4½°; Pegasid.—J. E. Clark.
10	11 43 p.m.	Birmingham.	2nd	Red	0.5 sec.	74 + 80 to λ Draconis	[Near P Andromedæ; 27 + 52.]	Left a streak; radiant η Perseid.—W. H. Wood.
10	11 44 30	York	1st		0.5 sec.	268 + 53 256 + 39		Path 10°; left a fine streak for 3 secs. Perseïd.—J. E. Clark.
10	11 50 p.m.	Birmingham.	1st	Green	0·5 sec.	56 + 55 72 + 53	[Uncertain; paths nearly superposed.]	Left a streak; radiant η Persei.—W. H. Wood.
10	11 51 p.m.	Bristol	= ♃		0·3 sec.	77 + 55 96 + 48		Path, 13°; left a streak.—W. F. Denning.
11	12 16 a.m.	Birmingham.	1st	Yellow	1·0 sec.	α Aquarii to δ Capricorni	[Uncertain: non-divergent paths.]	Left a streak; Perseïd.—W. H. Wood.
11	12 17 a.m.	Bristol	2nd		0·3 sec.	358 + 32 345 + 16		Path, 20°; left a streak.—W. F. Denning.
16	11 42 p.m.	Ibid	3rd		Rapid, 0·3 sec	2 + 2 351 − 7	[Uncertain; paths non-divergent.]	Path 13°; radiant 31 + 18.—W. F. Denning.
16	11 43 p.m.	Radcliffe Observatory, Oxford.	3rd		Rapid	ξ Aquarii to δ Capricorni		J. Lucas.
Oct. 2	11 32 p.m.	Bristol	3rd	White	0·5 sec.; rather slow.	89 + 31 91 + 20	[In Tarandus, at about 25 + 80; (perhaps head of Auriga?)]	Path, 11°; Aurigid II.—W. F. Denning.
2	11 33 p.m.	Radcliffe Observatory, Oxford.	3rd			ν Aurigæ to ½ (α, β) Tauri		J. Lucas.
29	10 56 p.m.	Bristol	3rd		Rapid, 0·2 sec.	82 + 15 77 + 9	[Accordance very doubtful. 91 + 25 (?)]	Path, 8°; left a streak; radiant in Gemini.—W. F. Denning.
29	11 0 p.m.	Radcliffe Observatory, Oxford.	1st	Blue	3 secs.	γ Tauri to Cetus		Left a long train.—J. Lucas.
Nov. 9	11 44 p.m.	Ibid	2nd		0·3 sec.	δ Eridani to between η and β Ceti.	[Near E. by N. horizon, or more S.; 145 + 8; 125 + 8; or 105 + 8?]	J. Lucas.
9	11 46 p.m.	Bristol	1st		Not very rapid. 0·5 sec.	66 + 4 46 + 1 [Accordance in end part of path only.]		Path 20°; left a streak; radiant 108 + 11.—W. F. Denning.
1878. Aug. 10	9 36 p.m.	Crediton (Devon).	= ♃		2·0 secs.	1° below ζ Pegasi; past α Aquarii	[Uncertain; paths not divergent.]	S. J. Johnson.
10	9 38 p.m.	Bristol	= ♃			321 − 10 312 − 23		Perseïd.—W. F. Denning.

APPENDIX.

I. Meteors doubly observed.

Among the lists of occasional observations of shooting-stars received by the Committee during the past year, a few examples occur of simultaneous observations by observers at distant stations of meteors which agree together in every particular of their description, and which, on account of the regularity of the watches kept, the few meteors noted on the same dates, and the good accordance also of the apparent paths when allowance is made for the observers' positions as regards length and direction of the base-line between their stations, were undoubtedly independent views of the same meteoric bodies, and will, therefore, afford approximate data of the distances and positions, and of the lengths and directions of their real paths. One additional observation of each of two meteors recorded in last year's Fireball List has been received, and the descriptions of those meteors, at $10^h\ 44^m$ p.m., June 10th, 1876, and $10^h\ 25^m$ p.m., August 10th, 1877, already given, are here repeated for comparison with the new descriptions of them which have since been received.

The radiant-points concluded from the recorded paths by their direct projections are added in the last column but one of the list. But to these positions, when the tracks nearly overlie each other, and therefore give results very largely and doubtfully affected by the errors of observation, too much importance must not be attached in respect of the variations which they sometimes show from the independent estimates of their probable radiant-points which were originally attached to them by the observers. Radiant positions thus found are yet data of the first and greatest interest to be extracted from such observations. A complete discussion of the heights, velocities, and other particulars of these meteors' real paths, and of those of a similar list of doubly observed shooting-stars presented in last year's Report, is postponed at present, until materials for a more general communication on the results of such comparisons present themselves in the course of future observations.

II. Large Meteors.

Many of the descriptions of fireballs seen during the past year have furnished reliable materials for determining their real courses and the probable astronomical relationships of their orbits. A condensed account of these occurrences is given in this Appendix, as most of the following notes were collected from very scattered sources, and are not the results of preparation and of systematic watches, like those of the foregoing Appendix. The two lists which are included in this Appendix contain the final determinations of the real paths of the most brilliant and widely observed of the past year's bolides and detonating meteors, and such accounts of others, not so widely observed, as private and published descriptions of them have enabled the Committee to collect.

On June 14th, 1877, $8^h\ 52^m$ p.m., Paris Time. The large fireball of this date seen in the south of France by M. Gruey at Clermont Ferrand (Puy-de-Dôme) was also observed at Bordeaux and at Angoulême with accurate positions by the stars. The agreement of the recorded paths with

each other and with a radiant point near ζ Boötis is very close, and this star was culminating at the time on the south meridian. The initial points of all the tracks begin so near it, probably by an extension to which there is a natural tendency in observations, that the initial height of the fireball thence obtained is without doubt much overrated, while its duration in seconds was very well determined by the independent estimations. There appears no reason (from the greatly overrated length of path) to accept M. Gruey's calculation that the real orbit of this fireball was a hyperbola of very great eccentricity, as the measure of its real length of path and velocity is based upon very questionable data? A loud detonation followed the meteor's disappearance at Bordeaux, 55 miles from its end point, in five minutes; the distance which sound would travel in that time is about 62 miles.

On October 19th, 1877, 6^h 13^m p.m., Ireland, and the West of England. A very magnificent fireball made its appearance westwards of the English coast, over Ireland and St. George's Channel, during full twilight, and before any stars were yet plainly visible, on the above evening; and many accounts of its unusual appearance were presented in the daily journals. The strength of the daylight hindered all definite measures of its position, and a solitary description by the stars at Monmouth, together with a careful sketch of its course forwarded to the Committee from an observer near Dublin by Professor Ball, of the Dunsink Observatory, are the only available accounts among a score or two, for determining the real direction of its course! Its flash was like lightning at Swansea, amid the glow in the west lingering after the departed sun. By the few who saw the meteor itself, it is described (at Weston-super-Mare) as a balloon of whitish light, falling slowly; at Stoke Prior, Wolverhampton, as a glowing poker rushing through the air; and a strange spectacle seems to have been presented by it (as described in the 'Times' of October 24th) near Templemore, in the south-west part of Ireland. "We had one of the most brilliant meteors here last evening that I ever saw; indeed, it was rather startling, as the whole heavens seemed open, or rather divided. It was a quarter to six o'clock (Irish time), and I was on the terrace when I suddenly heard a crackling noise, or rather the intense light and noise came together. I looked up and saw a great light. The meteor went from east to west. I did not see it fall to earth, as it seemed to vanish away into space. It began small, then grew alarmingly large, and gradually disappeared, although the light remained visible for over seven minutes. I called M. from the piano, and A. ran down from my room wondering what had come to pass. I went down (100 yards off) to call K. and his family to look at the light, which was still very bright, though not so intense as it had been, and which had then assumed a semicircular shape, and gradually grew paler. It was quite seven or eight minutes visible. I shall never forget the sight, it was so grand and awful." Templemore is in the direction from Monmouth which the meteor took, as it descended vertically, in the position there noted near Arcturus; and the alarming nature of the spectacle seems to indicate that its nearest approach to the earth must have been not very far from Templemore.

The observer (Mr. John Parker) near Dublin, also gives a singular description of its appearance. "First indication:—A momentary brilliant illumination of all surrounding objects, casting a well defined shadow, as in sunlight, and not such as is caused by lightning.

RESULTS OF DOUBLE OBSERVATIONS OF LARGE FIREBALLS VELOCITIES, AND

Date and Hour (Local Time, or) G. M. T. Size and General Appearance.	Principal Places of Observation	Meteor's Real Course.	
		Beginning; Height and Locality.	End; Height and Locality.
1876, July 8 (8^h 45^m p.m.)	Ind. and Ohio, U.S.	88m. Ottohee, Ohio	34m. L. Michigan
1877, Jan. 19, 6^h 27^m p.m.	Wales, and S. of Ireland	75m. Milford Haven	45m. St. G. Channel
" April 6, 9^h 26^m p.m.	Wales, and S. of Ireland	80m. Kildare	20m. Cape Clear...
" April 16, 10^h 50^m p.m.	Leicester; I. of Man ...	60m. Yorkshire	30m. Yorksh. Coast
" June 14 (8^h 52^m p.m.); = full moon at last; white, with tail of red and blue. Detonation in 5 min. at Bordeaux.	Clermont Ferrand, Angoulême, and Bordeaux, France.	175m. (?); 20m. S.W. of Nerac, Gers.	27m. 10m. W. of Biberac, Dordogne 55m. from Bordeaux.
1877, Oct. 19, 6^h 13^m p.m. Globular, white nucleus. Left a bright white streak, becoming serpentine, for 8 or 10 minutes.	Monmouth, Swansea, Bath; and Dublin, Waterford, and Templemore, Ireland.	60m. over Milford Haven.	40m. over Cape Clear.
1877, Nov. 20 (afternoon). Splendid fireball, with flame-track, and long-enduring cloud-streak. Violent explosion over Danville, Halifax, &c., N. Carolina.	Richmond, Washington, Bristol, Halifax, &c., in Virginia, and N. Carolina, U.S.	70m.; 15m. N. of Danville, Virginia.	10m.; 25m. a little S. of E. from Danville, Virg.
1877, Nov. 23, 8^h 24^m p.m. Great detonating meteor; ½ diam. of moon; of extreme brilliancy; streak 40 miles long, 2,000 ft. diam.; explosion very loud in I. of Man, N. Wales, and Cheshire.	England, Wales, Scotland, and Ireland.	96m.; 15m. N. of Derby. 40m. over Liverpool; first outburst; the meteor suddenly became very luminous.	14m.; 17m. N.N.W. of the Great Orme's Head.
1877, Nov. 27, 10^h 26^m p.m. Blue, globular with sparks; ⅓ diam. of moon in middle of its course; small in first and last parts. Motion curved, extraordinarily slow; about 22 seconds.	Greenwich, Writtle near Chelmsford, and Bristol.	56m.; 11m. N. of Margate, Kent.	13m.; 12m. W. of St. Omer, France.
1878, March 25, 10^h 22^m a.m. Large meteor, in sunlight. Conical; white or red ball, with long taper tail of fire; burst at last; smoke wreath remained visible 10 minutes.	Coupar, Callander, Newcastle, Hawick, Wigton; Scotland and the North of England.	50m.; 30m. E.S.E. from Berwick.	22m.; 45m. E.N.E. from Aberdeen
1878, May 12, 8^h 53^m p.m. Very brilliant head; white, with not much tail; dropped a red fragment near disappearance; report heard in 2 minutes, like thunder, at Galashiels.	Edinburgh, Bathgate, Galashiels, Stonykirk; York, Scarborough, and the middle of England.	78m. over Northallerton, Yorkshire.	17m.; over Boness, near Edinburgh.
1878, June 7, 9^h 53^m p.m. ¼ diam. of moon; bluish; pear-shaped, with flickering tail; long, slow course, with uniform size and brightness; no streak or sparks.	Bristol and Shrewsbury; Knole and Hawkhurst, Kent; West and South of England.	65m.; 20m. W.N.W. from Guernsey, Channel Islands.	37m.; 15m. E.N.E. from Lundy Isle, Bristol Channel.
1878, July 29, 9^h 25^m or 30^m p.m. ⅓ ☽. Two flashes, the first vivid, white; burst into red fragments leaving a long momentary red-starred track; motion pretty swift.	Manchester, Lancaster, Cumberland and N. Wales.	82m.; 8m. W. from Manchester.	20m.; midway between Preston and Blackpool, coast of Lancashire.

SEEN IN THE YEARS 1876–78; SHOWING THEIR REAL PATHS, RADIANT POINTS.

Distances ('m.', or 'miles') in British Statute Miles.		Nearest known Radiant Point; and Remarks.
Length of Path and Velocity.	Observed Radiant Point α δ	
145 miles	305° + 7°	T. 35. Streak visible 45m. (For full accounts, see vol. of these Reports for 1877, pp. 149, 156.)
230 miles, 35 miles p. sec.	135 + 27.....................	D. 8 (1877); = ½ ☽ ; no streak.
165 miles, 31 miles p. sec.	275 + 50...	Draconids I. (G. 47). Detonated.
170 miles (?)	140 + 50 (?)	G. 45 (?); 3 × ♀.
170 miles (?) in 4 secs. (three estimations); vel. 42½ miles (?) p. sec. (parabolic speed 11 miles per sec).	212 + 12 (± 3°), near ζ Boötis.	202° + 9°, May, Heis. 210° + 20°, July 4-11, G. 89. (No known radiant near this place in June.) Calculation of the meteor's real path by M. Gruey, 'Comptes Rendus,' 1877, Oct. 1; vol. lxxxv. p. 632.
Very uncertain path; accurately described at Monmouth only, and roughly in Dublin.	20 + 15 (?) near η Piscium (assuming the course to have been nearly horizontal).	Piscids II. 20° + 14° Oct. 13-29, 1876, Denning. Slow meteors. (No dependence can be placed on *the assumed* position of the fireball radiant.) A very splendid meteor; the streak perhaps sunlit.
About 70 miles (as deduced from this position).	About alt. 60°, 35° N. fr. W. (by this description).	Description of the meteor's real course by Prof. H. A. Newton. (Letter in the 'Richmond (U.S.) Daily Dispatch,' Dec. 13, 1877.)
133 miles. Velocity (from 25 estimations of duration), 17½ miles per second; (parabolic speed 19 miles per second.)	62 + 21 (± 3°) near ε Tauri.	A slight alteration of the radiant (diminishing its longitude) brings the orbit nearly into coincidence with that of the comet of 1702. A well-known radiant, Taurids I. (Calculation of the course by G. L. Tupman, 'The Observatory,' vol. i. pp. 316 and 351.)
78 (± 5) miles in not less than 15 seconds. Velocity not greater than 5 miles per second).	285 (± 1) + 64 (± 5), at ½ (δ, o) Draconis. [= G 166; Schmidt, Heis, Nov. 1-15; Clark, and DG_3, Nov. 23—Dec. 9.]	The real orbit of the meteor cannot have been far from circular. Period 549 days about; motion direct, with inclination about 30°. (See the calculation of its path, p. 270, by G. L. Tupman).
130 miles. Duration of the whole flight about 7 sec.; velocity 18½ miles per sec.	332 − 20 (± 5°)	Radiant a little S. of the Ecliptic. Directed in its real orbit very nearly from the sun's place (R.A. 4°½, N. Decl. 2°).
155 miles in about 10 seconds for the whole course; 15½ miles per sec. (parabolic speed 15.5 miles per sec.).	214 − 7 (± 4°) near ι Virginis.	D 46 (1877), 210° − 10°; rich and probably new shower; Corder, Apr.—May, 1877, 208–6; Forshey, Apr. 18, 1841, 198°–8°.
160 miles in 8 or 9 seconds; about 19 miles per second. (Parabolic speed 20 miles per second.)	247 − 25 (± 5°); close to Antares.	Radiant of fireball, 1873, June 17th, Austria and Bohemia (Galle, and von Niessl), 248°–20°.
70 miles in about 3 secs., 23 miles per sec. (Parabolic speed 21 m. per sec.).	290 + 42; near δ Cygni; (or between 285° + 45° and 300° + 35°).	Denning, end of July, 1878, 284° + 44°; a radiant of bright slow-moving meteors.

The meteor appeared as a distinct well-defined silver-coloured streak, W.S.W. of Dublin, forming a spiral curve, with a distinct head or nucleus of *white* light, which after being visible for nearly two seconds, burst into fragments with a loud noise [?] The spiral streak continued visible for seven

FIG. 1.

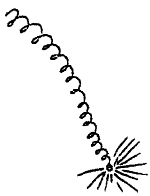
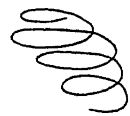


FIG. 2.



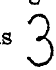
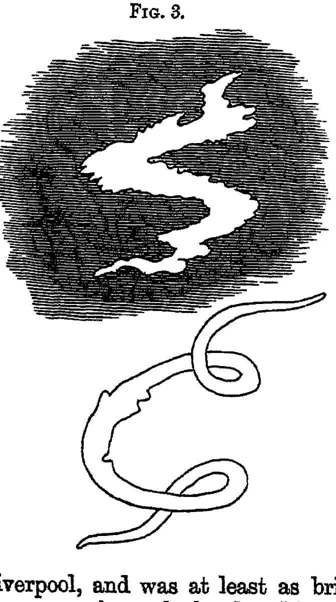
minutes, during which time the spiral form became more and more developed, until the circles became lost by evaporation. The sky was clear and the atmosphere calm." At Newtown the meteor fell from near the zenith to S.W., leaving a streak for nearly a quarter of an hour which curled on itself thus  and afterwards acquired this form . Its cloud-masses must have been lighted up by the sun's rays, and were more striking, even, it would seem in England than they have been described in Ireland. The appearance which it exhibited at Monmouth is noted in Mr. Watkins Old's observation of its course in the accompanying Fireball List. Mr. A. W. Batson, of the South Wales Institution at Swansea, who is a good artist, made two sketches of it, which are thus referred to in the 'Standard' of October 23rd:—"The meteor fell perpendicularly, almost due west, over the light of the sun. After its disappearance there remained an immensely bright, jagged trail of light, which gradually assumed a spiral form, and floated in a southerly direction. In its last form it looked like a letter C with flourishes. This phenomenon was visible for fully ten minutes, at the end of which time it dissolved into a cloud of phosphorescent light."

FIG. 3.



1877, November 23rd, 8^h 24^m p.m., Lancashire, and most parts of England, Wales, Scotland and Ireland. Accounts of this detonating fireball, which appeared as large as the full moon at Manchester and Liverpool, and was at least as brilliant, appeared in a great many contemporary journals, local and leading newspapers, and scientific periodicals, very quickly after its occurrence. A letter from Captain Tupman, of the Royal Observatory, Greenwich, in the 'Times' of November 30th, soliciting particular accounts of its appearance from observers in Wales,

Lancashire and Cheshire, was responded to by fully 120 communications, the substance of which Captain Tupman has discussed and presented in three papers, which are contained in the first yearly volume of the newly edited and published journal of Astronomy, 'The Observatory' (at pp. 282, 316, and 351). The general features of the fireball, and of two others seen on the same evening, are discussed, with a plate of several phases of its appearance seen by Mr. Plant at Manchester, in the first; and the materials furnished for comparison, with particulars of the individual accounts, and with the final results to which their examination led him, are presented in the remaining two of Captain Tupman's papers. The same letter in the 'Times' which invited these communications also described a meteor of singular interest and brightness, seen by Captain Tupman at the Royal Observatory, Greenwich, on the night of November 27th, which will be the subject of the following paragraph of this Appendix. A striking statement of an observer at Queenstown, Cork Harbour, followed in a few lines after the impression of the same letter, that at the hour of the fireball's appearance a meteor of extreme brilliancy was observed travelling, in bright moonlight, across the northern sky, showing the vast extent of country over which this large meteor, which burst forth directly over Liverpool, was satisfactorily observed. A fireball only slightly less conspicuous was, it appears, noticed at several places at $7^h\ 25^m$, an hour before the appearance of the large one, and sufficient accounts of its course and apparent path were forwarded to Captain Tupman from observers who were fortunate enough to witness both meteors, to show that it was probably a member of the same meteor stream and diverged from the same radiant-point as the larger one. A detonating fireball of great brilliancy was also seen at Strassburg, on the same evening, at 6 o'clock p.m.*

The position of this fireball focus, or centre of emanation of at least one detonating or aërolitic fireball of the 23rd of last November is sufficiently remarkable to become the source of a new series of conjectures and researches regarding any aërolitic or detonating meteors that may in future times be observed; for it was discovered that in the real direction of its flight this unusually striking fireball's radiant-point agrees in position with that of a very notable and important star-shower diverging from near the Pleiades and Hyades in the middle and early part of November. The star-shower thus indicated, known, since Mr. Denning's and Mr. Corder's successful investigations of it in November, 1876, as "Taurids I.," was found by Mr. Denning, among frequent rich displays of its meteors in that year, to reach a conspicuous maximum on the morning of November 20th, 1876, with a radiant-point marked with the greatest certainty at $62° + 22°$. It is exactly at this place that by a complete discussion of all the observations furnished to him, Captain Tupman found that the great detonating meteor's radiant-point of the 23rd of November last was situated. It is thus a very plain and obvious inference that the shooting stars forming the body of the stream which the earth encounters striking it from Taurus about the middle, and on a few later nights of November, are of the same hard, compact materials, in smaller fragments, as that of which the fireball must have been composed to produce the loud and violent concussion of the air with which its explosion was marked by a thunder-like report in Wales, Lancashire, and the Isle of Man.

* 'Strassburg Gazette;' and 'Nature,' vol. xvii. p. 114.

The "Taurids I." are apparently small aërolites; and it may be added that the comet of 1702, whose fragments, if they strike the earth at all, must do so from a radiant point at about 56° + 20° on the 27th of November, appears to be so closely associated with the new-found maximum of the "Taurids I." on November 20th, that if the aërolitic character of that meteor shower is certainly established, a fair presumption then suggests itself that the material of the comet itself is a firm and solid substance, and that the "Taurid" shooting stars, and even detonating fireballs which sometimes accompany them, are but small fragments compared with much larger stony masses which may be pictured as congregated together in the nucleus of the comet!

Besides the many scattered accounts, and the general review of their contents given, with an engraving, by Captain Tupman, in his first Paper, a full and varied collection of descriptions of the meteor's appearance by different observers was published in 'Nature' (vol. xvii., pp. 94 and 113). Particulars of these various descriptions, including some original accounts, will be found in the list of observations of large meteors accompanying this Appendix; and the real height and description of its course, from 96 miles above the neighbourhood of Derby to a point 14 miles above the Irish Channel, about 20 miles north of the Welsh coast near Llandudno, are detailed at length in the list of such determinations (pp. 266–7) of several large meteors during the past year which is here appended. The meteor's apparent path was noted pretty exactly at ten, and less perfectly at five or six other places in England and Wales, Scotland and Ireland, by the stars or planets; by estimated bearings and altitudes at some twenty-five places, and by exact measurements of the same data at four or five. From two observations of the latter kind by Mr. T. S. Petty, at Llandudno, and by Captain Watson on board of the *Algeria*, in the Irish Channel, very near the meteor's place of disappearance, Captain Tupman regards the final height as having been only 14, instead of 26 miles, and the radiant-point at 62°+21° instead of at 63°+15°, which were the first deductions of its real course arrived at from the other observations. Whatever discrepancies in the end-height and radiant-point are thus exhibited, the adopted corrections thus finally introduced appear to be absolutely necessary ones to satisfy some of the nearest well-observed positions, and especially the two last-named very important observations. Of the two explosions, or first outburst and final disruption, between which the meteor was a most vivid bluish pear-shaped fireball, with a long tail of red stars or sparks following it, the first took place at a height of about 40 miles exactly over Liverpool, and in a considerable part of its track before this point the meteor was described as resembling an ordinary shooting-star. It left no long persistent streak, and burst at last into a shower of highly-coloured fragments with an explosion, the report of which was loudly heard in two or three minutes like artillery and thunder on the Lancashire and Welsh coasts, and in the Isle of Man.

The following is the calculation by Captain Tupman of the real course of the bright fireball which he observed on the evening of November 27th, 1877:—

A METEOR *of Short Periodic Time.* *By* Captain G. L. TUPMAN.

On the 27th of November, 1877, at 10^h 26^m G.M.T. precisely, the sky being clear, I observed a fine fireball, of normal type, descend from

about 6° above the star *Castor* to a point about 5° or 6° to the left of *Sirius*. The terminal point was exactly the same altitude as *Sirius*, and about the same distance to the left. The meteor began as a first or second magitude star; and, after traversing one-fourth or one-third of its path, it suddenly increased in brilliancy and apparent size to a fine bluish-white fireball, and emitted a train, coloured blue, red, and green, many degrees long. At this time the pear-shaped ball was 10 or 12 minutes in diameter. At about two-thirds of its course it began to diminish in lustre, and, turning a dull red colour, moved very slowly towards the end, so slowly, that it seemed to come almost to a standstill. It was then seen through a thin cloudy haze, and was about equal to *Sirius* in lustre. I counted 22 seconds duration, making a mental allowance for the time that had elapsed before I commenced to count; but immediately afterwards, by imagining the course to be described again, I thought the duration was 15 or 16 seconds. It could not have been less than 15, and may have been 20 seconds. The path was gently curved towards Orion. The place of observation was half a mile East of the Royal Observatory, Greenwich.

The meteor was also seen by Mr. Henry Corder, at Writtle, near Chelmsford, who thus describes it:—

Nov. 27, $10^h\ 25^m$—At the commencement it was of the 3rd or 4th magnitude, rapidly increasing to first magnitude, of deep red colour and red train. Then equal to *Venus*, greenish blue. It began 83° + 31°, ended 91°—1° in a cloud. Path 38° long, traced on the chart among the stars of *Taurus* and *Orion*; parallel to *β Tauri* and *α Orionis*, and when produced the path coincided with 5 Monocerotis. Mr. Corder supposed that the meteor ended at the extinction of the bright light, all further view being cut off by the clouds. The duration was not noted, as he endeavoured to call the attention of a friend; but he was struck by the great length of time it remained visible—estimated at about 5 or 6 seconds.

The real ending was seen by Mrs. Ursula Ware, at Clifton Down, Bristol, at an altitude equal to that of *Sirius*, and about 1° to the left of the vertical of Procyon [by a diagram]. It moved very little during the 3 seconds it was visible. Time $10^h\ 40^m$.

These descriptions afford the following coordinates as basis of calculations:—

	Began		Became Bright		Became Dull		Ended.	
	Azimuth	Alt.	Azimuth	Alt.	Azimuth.	Alt.	Azimuth.	Alt.
Greenwich	N. 85° E.	44°	S. 81° E....	34°...	S. 69° E ...	20°	S. 59° E....	6½°
Writtle ...	S. 67 E.	50	....	....	S. 51 E....	23	....	......
Bristol ...	....	....	....	....	....	....	S. 79½ E ...	4½

These positions are in remarkable agreement, and the following true path satisfies them all, both azimuths and altitudes, within 1°.

When the meteor first became visible, it was at the real height of 56 statute miles vertically over a point off the mouth of the Thames, 11 miles north of Margate, or in lat. 51° 33′ N.; long. 1° 21′ E. It moved in the direction S. 26° E., in a path inclined 35° to the horizon, and disappeared at the height of 13 miles vertically over a point 12 miles west

of St. Omer, in France, or in lat. 50° 45′ N.; long. 2° 0′ E., the total length of the path being 78 miles ± 5 miles.

The radiant point is obtained with precision in 285° + 64° (neglecting the slight zenithal deflection, the Right Ascension being certainly within 1°, the Declination within 5°), corresponding to 340° of longitude and 7° of ecliptic North Polar distance.

The other elements required are—

	° ′	
Longitude of the sun......................	245 50	
Longitude of the apex of the earth's motion	156 25	
Log. radius vector	9·99394	
Earth's orbital velocity....................	19·1	statute miles per second.

Now assuming, as usual, the meteor to have been moving with the velocity due to a sensibly parabolic orbit—that is to say, $19{\cdot}1 \times \sqrt{2}$, the aberration of the radiant would have been 44° 35′, and the relative velocity 16·9 miles per second. The meteor then would have traversed the 78 miles of its visible path in about $4\frac{1}{2}$ seconds of time, or the 50 miles of it seen by Mr. Corder in less than 3 seconds. Altering the position of the radiant, even as much as 10° in the direction of *maximum* effect, *i.e.*, away from the apex of the earth's motion, produces no sensible effect upon this "parabolic" duration.

The actual duration was certainly not less than 15 seconds; it may have been 20 seconds (I should say it was 17 seconds, for I frequently test my habit of counting seconds, and generally find it about 5 per cent. too slow.) It is impossible that I can have been many seconds in error in counting 15 or 20. Mr. Corder was struck by the long duration. He made no attempt to count it, as he tried to call the attention of a friend. His rough estimate of 5 or 6 seconds refers to about two-thirds of the visible path.

Taking 15 seconds as the real duration, the relative velocity is only $5\frac{1}{4}$ miles per second, corresponding to an orbital velocity for the meteor of 20·4 miles per second. Since the radius vector is common to both orbits, we have the relation—

$$V_1^2 \rho = a \left\{ V_1^2 - V^2 (2 - \rho) \right\}$$

where V_1, V are the orbital velocities of the earth and the meteor respectively, a the mean distance of the meteor's orbit, that of the earth being 1, and ρ the common radius vector.

Whence $a = 1{\cdot}1691$, corresponding to the periodic time 462 days, and the other elements of the orbit are—

$$\begin{aligned} q &= {\cdot}9858 \\ \epsilon &= {\cdot}1568 \\ \phi &= -4^\circ\ 16' \\ \pi &= 70^\circ\ 6' \\ \Omega &= 245\ 50 \\ i &= 15\ \ 0 \end{aligned}$$

Motion direct.

I will now suppose that the actual duration was only *one-half* of that taken before, that is only $7\frac{1}{2}$ seconds. As the radiant point is determined with a degree of accuracy that will not allow it to be shifted many degrees farther away from the apex, the true orbital velocity of the meteor, on

this extreme supposition, is no greater than 21·5. Thence the mean distance 1·3785 corresponding to a periodic time of 591 days, the other elements being—

$$\begin{aligned} q &= \cdot9859 \\ \epsilon &= \cdot2848 \\ \phi &= -\ 2^\circ\ 29' \\ \pi &= 68\ \ 19 \\ \Omega &= 245\ \ 50 \\ i &= 21^\circ\ \ 9' \end{aligned}$$

It is not worth while to consider the case of the duration having possibly been much greater than 15 seconds; for had it been so great as 30 seconds, the elements of the orbit would be sensibly the same as for a duration of 15 seconds.

It is remarkable that the elements of the orbit of this meteor, with the exception of the inclination (i), are determined with a degree of accuracy equal to those of a well-observed comet. The node is, of course, given, by the mere record of time, within 3″: the perihelion distance is accurate to the fourth place of decimals: the anomaly (ϕ) and the longitude of the perihelion are within a few minutes, while the mean distance and eccentricity must be very approximate. Such favourable conditions, however, as the present will rarely happen.

Many observers have recognised a radiant point of shooting stars very near to that of this fireball, and about the same date [see Mr. Greg's comparative list, in 'B. A. Report,' 1874]; but there are as yet no records of the apparent velocity of the meteors. If the radiant be persistent and the apparent velocity of the meteors be slow, there must exist a meteoric ring of nearly circular form occupying the position in space defined by the elements given above.

So far as I am aware, the assumption of a parabolic orbit has satisfied, within probable limits of error, all previous observations of this character. Hyperbolic orbits for fireballs have been deduced, but only on the assumption that the observed durations were accurate. Experience proves that the most reliable observers cannot avoid errors of 10 or even 20 per cent., and that in favourable cases of long duration.

The orbit deduced above for the fireball of 1877, Nov. 27, is independent of any reasonable error in estimating the duration. It is sufficient for the establishment of a short periodic time (such as 500 days) that the meteor "moved slowly" from a fairly well-determined radiant point, distant about 90° from the point in the heavens towards which the earth's motion was directed.

On the Perseïds I. 1876, *August* 9, 10, 11. *By* Captain G. L. Tupman.

On the three evenings above mentioned, while residing at St. Moritz, in the Engadine, I set myself the task of determining the position of the Perseus radiant as accurately as possible. I watched the immediate neighbourhood of the radiant, and only took account of those paths which from falling favourably among stars could be mapped with great accuracy. The number of such paths obtained was of course very limited, but they are more valuable for the purpose than a large number of roughly recorded paths. I made use of Mr. Proctor's 'New Star Atlas,' first edition. It is not to be supposed that the determination of the exact point of beginning and ending of each track was attempted—that would

serve no useful purpose—the care was expended on the *true direction* and general position of the paths.

The following observations of true Perseïds were obtained:—

	Local Mean time	Beginning	End	Mag.	
1876.	h. m.	° °	° °		
Aug. 9.	8 50	199 + 56	209 + 20	♃	Swift, bright streak.
	9 5	191 + 57	199 + 20	♃	Very swift; streak very fine.
	9 22	19 + 59	355 + 58	♀	Very swift; very bright.
	9 40	223 + 60	221 + 20	♀	Very swift; very bright streak.
	9 45	222 + 30	220 ± 0	♃	Very swift.
	10 0	255 + 16	246 − 3	♀	Very swift; bright streak.
Aug. 10.	9 30	204 + 50	210 + 17	2	Very swift: streak.
	9 35	19 + 58½	0 + 58	♃	„ „ streak.
	9 50	23 + 60½	348 + 58	♃	„ „ streak.
	9 55	218 + 75	218 − 45	♃	„ „ bright streak.
	11 30	29 + 41	23 + 32	2	„ „ streak.
	11 35	39 + 44	34 + 27		
	11 40	25 + 63	351 + 62		
	11 45	0 + 60	339 + 53		
	11 55	37 + 60¼	33 + 61½	♀	Nearly stationary; 1° long; half as broad; many seconds; very red.
	12 0	49½ + 58	Stationary	♃	Almost stationary; very slight motion; less than ½°, away from Cassiopeia.
Aug. 11.	8 53	45 + 77	235 + 81	1	Very swift.
	8 55	80 + 57	87 + 56½	1	Slow; red; streak.
	9 0	0 + 72	330 + 72		Rather slow.
	9 40	70 + 59	79 + 59		
	10 5	58 + 58	65 + 57½		Slow.

	h. m. h. m.			Mean Alt. of the Perseus Radiant.
Aug. 9,	8 50 to 9 50,	counted	5 Perseïds and 4 others	24°
Aug. 10,	9 30 to 10 35,	„	20 Perseïds and 15 others...........	28
„	10 55 to 12 0,	„	22 Perseïds and 9 others............	37
Aug. 11,	8 55 to 10 38,	„	26 Perseïds and 22 others	26

I find the radiant point to be distinctly double. 12 of the above tracks indicate with great precision the position 46° + 57°·6, and 8 give 38° + 56°·0 with equal accuracy. Although hardly 4° apart, I have no doubt these two centres of radiation are distinct.

1878, March 25th, $10^h\ 22^m\ 30^s$ a.m. Forfarshire and the east coast of Scotland. The fireball, described as brilliant in daytime, and in bright sunshine, in Scotland and in the northern counties of England on this date, pursued its visible course over the North Sea from a height of 50 miles over a point 30 miles E.S.E. from Berwick to a height of scarcely more than 20 miles over the sea 45 miles E.N.E. from Aberdeen. This path is 130 miles long, descending with a slope of about 13°, from 5° or 6° W. of South, towards 5° or 6° E. of North, referred to the horizon of places near Dundee and Aberdeen. Of the duration of the meteor's flight in this course but few accounts were preserved; but at a height of 35 miles when it was off Arbroath ("a little north of east" from Callander),

110 miles north from Newcastle-on-Tyne, and 75 miles in a direct line from Dunbar, a first outburst of sparks and scintillations (seen at Callander) seems to have taken place, agreeing nearly in its altitude (16°) with the apparent altitude of 12° or 15° at which it first attracted observers' attention by its unwonted size and luminosity, at Newcastle. It is in the last 60 miles of its path from this point that durations of its flight varying from one-and-a-half to two seconds were noted at Newcastle and at Callander; while an observer, apparently of its whole path, near Stranraer, gives four seconds for its duration. Either of these estimates gives nearly 35 miles per second as its real speed of flight. The radiant point was at 332°—20° (R.A. and Decl.), and the speed of a meteor from this radiant point with a parabolic orbit is 33 miles per second; a velocity which the observations therefore substantiate very nearly. Measurements of the meteor's course at two places near Callander, and at two places near Newcastle-on-Tyne, as pointed out by observers there, were obtained by Professor Herschel, and corroborated each other at those places within a few degrees. In answer to a request for similar measurements addressed to observers of the fireball in the 'Scotsman' of May 1st, by Professor Herschel, a very exact description of its apparent path by carefully observed positions of the line of light, or cloud-streak left upon its track, at Coupar Angus, 15 miles N.W. from Dundee, was sent to the Committee by the head railway porter of that station, Mr. John Robertson. And good accounts of its course at Wigton and Hawick, in the south-west part of Scotland, and at Darlington, as a more distant point of observation in England, were also recorded, of which the collected statements carefully compared together, combine to fix with considerable certainty, and with a degree of accuracy which only admits of very small corrections, the height and situation, and the real direction and velocity, of the meteor's course, as above described. A peal of distant thunder, heard at about the time of the meteor's appearance at Dunbar, is perhaps attributable to it, though the distance of the nearest point of the meteor's track was there 70 miles, which sound traverses in five minutes and a half; and throughout its course it was indeed between 50 and 70 miles distant from all the easternmost points of the coast, and from the principal towns of the east part of Scotland, where it was very widely noted and observed.

The real direction of this fireball's motion round the sun and arrival upon the earth is remarkable, as but little below the ecliptic (about 9°), very nearly at the place which would belong to the path of a body projected with parabolic velocity directly from the sun itself. In its real orbit it approached the earth from a point of the heavens within 10° of the sun's place (about 3° behind it in longitude, and 9° south of it in latitude), which was in the ecliptic at longitude $4\frac{1}{2}$°. The following table gives the elements of its orbit, supposing it to have been parabolic: and the conclusion arrived at from the observations is that the perihelion distance, or the least distance of the meteor in its orbit from the sun's centre during its closest approach to and passage round the sun, was about $\frac{1}{45}$th (0·022) of the earth's distance from the sun, or about four of the sun's radii distant from its surface as it neared it, and made the rapid circuit of its sharply returning orbit round it!

$$\left.\begin{array}{l} \Omega = 184^\circ\ 30' \\ \pi = 358 \\ i = 70 \\ q = 0{\cdot}022 \end{array}\right\}\text{Motion retrograde.}$$

A LIST OF FIREBALLS SEEN DURING AND

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size.	Colour	Duration	Position or Apparent Path
1871.	h m					
Sept. 4	9 30 p.m.	Ross, Herefordshire.	5 or 6 × ♀	....	Moved slowly	Beginning at alt. about 30° N.E., and disappearing at about alt. 10°, due N.
1876.						
Jan. 29	About 9 p.m.	St. Mary's Oscott [?].	Bright meteor ...	....	....	Passed through Andromeda.
Feb. 27	6 15 a.m.	Melrose, Scotland.	Bright fireball ...	....	....	Passed from N. to S.W.
May 8	8 45 p.m.	Ibid	Brilliant meteor.	....	....	Moving towards S.W.
Jun. 10	About 10 40 p.m.	London	Nucleus rather small, but bright and dazzling.	Beautiful blue colour.	Rather swift.	Between Leo Minor and Leo Major
July 15	11 7 p.m.	Clapton, London.	Very fine meteor.	....	....	Began just below α Pegasi, and disappeared at or near ω Piscium.
Aug. 7	9 37 p.m.	St. Germain en Laye, France.	Large fireball ...	First white, then brilliant green.	About 2 seconds.	Began in the Constellation Lyra, and passed immediately below that of Aquila.
Sep. 23	7 40 p.m.	Melrose, Scotland.	Bright meteor ...	....	....	Passed from N.W. to S.E.
Nov. 8	5 35 p.m. the same hour, 5h 5m p.m. G. M. T., to a minute, as that of the large fireball seen in England.	Rossinière, Vaud, and generally observed in Switzerland.	Large fireball ...	....	....	Point of first appearance close to α Tarandi (Bode) at ½ (Polaris, ε Cassiopeiæ); [25° + 76°.] Disappearing at alt. 20° or 21°.
Dec. 13	4 45 p.m.	Northfield, near Birmingham.	Brighter and larger than ♀ appears at night	White	Motion quick (no time to call attention).	In the S.E., from about alt. 60° to about 30°
1877.						
Feb. 11	7 40 p.m.	Birmingham ...	Very brilliant meteor.	....	Motion very slow, compared to that of most meteors.	In the north-west; no part of its path having a very great apparent alt.

BEFORE THE YEAR ENDING IN AUGUST, 1878.

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
....	[Near δ Aquarii by the combined paths; 345°—15° (±4° in R. A., and ±8° in Decl.]	Like a large roman-candle ball. [The same meteor's apparent path and appearance at Durham is recorded with a sketch in these Reports. Vol. for 1872, p. 74.]	H. Southall (communicated by G. J. Symons.)
....	From E. to W.	....	Communicated by G. J. Symons.
....	....	....	Id.
....	....	....	Id.
....	Moving in a direction from N. to W.	Its light in the West attracted attention to it; end of its path concealed by trees; no train. Also observed at Writtle, Chelmsford, see these Reports, vol. for 1877, p. 104.	Frank Dennett. 'English Mechanic,' vol. xxiii., p. 404; June 30, 1876.
....	....	....	J. D. H. Ibid. p. 485, July 21, 1876.
....	Directed towards Saturn......	Nucleus white and brilliant when first seen, expanded just before disappearance like a green fire-work.	E. Ferrières. 'Comptes Rendus,' vol. lxxxiii. p. 459 (Aug. 14, 1876).
....	....	....	Communicated by G. J. Symons.
....	Fell quite perpendicularly. [Radiant in Cepheus or Lyra ?]	End of path hidden behind a mountain-top, 2 miles from, and 4,000 above the observer's point of view.	M. F. Ward (communicated by G. J. Symons.)
....	Descending thus  [Probable radiant point near foot of Boötes.]	Globular nucleus. In clear, bright sky, with no stars, yet clearly visible. [Other descriptions of this meteor appeared in these Reports, vol. for 1877, pp. 114–116.]	Mrs. F. Impey (communicated by J. E. Clark.)
....	Travelling towards the North	....	'Birmingham Daily Post,' February 14, 1877.

A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1877. Apr. 20	h m About 9 p.m.	Newcastle, Wicklow, Ireland.	Brilliant meteor.	....	Only a few seconds.	Passed from N.W. to S.E.
May 21	About 6 p.m.	Fianarantsoa, Madagascar.	Large fireball; detonating.	Fiery red encircled by blue; halo and tail comet-like.	....	Passed overhead. [The day had been peculiar, and the morning at Fianarantsoa so alarmingly dark that the market place was deserted.]
May 30	11 26 p.m.	Writtle, near Chelmsford, Essex.	Small at first; at last = ♃.	Orange; then bluish white.	Rather slow; 2 seconds.	From 335° + 47½° to 319° + 36°; observation very accurate.
Jun. 16	9 30 p.m.	Birmingham ...	= ♃	Reddish; then white.	3·0 seconds.	From o Leonis to α Cancri.
July 24	9 15 p.m.	Bridport, Dorsetshire.	= ♃	Red............	2½ seconds.	From 20° N. of E., alt. 30°, to alt. 10°, due E.
30	9 p.m.	Pontresina, Engadine.	= Sirius	Yellow	Slow speed.	From 245° + 4° to 228° − 3°
Aug. 11	1 a.m.	Writtle, near Chelmsford, Essex.	> ♀	Greenish......	1 second.	From 80° + 45° to 75° + 32°
17	8 13 p.m.	Putney, London	As bright as the moon in its first quarter.	Bluish green.	About 2 or 3 seconds.	From near β to near ω Piscium; from 344° + 2° to 357½° + 6°, as the best approximate position.
17	8 14 p.m.	Colchester, Essex.	About half the apparent diameter of the moon.	Very pale, or white; red sparks......	....	Shot across the S.E. heavens.
31	7 45 a.m.	Ballinasloe, Ireland.	A very brilliant meteor.	....	....	In the West ......
Sept. 7	(About 10 5 p.m.)	Bloomington, Indiana, U.S.	Large meteor......	....	Seen for a second or more.	Remained almost stationary where it appeared (in Vulpecula) at about 295° + 15°.

THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
....	....	The illumination of the meteor lit up the sky.	(Communicated by G. J. Symons.)
....	....	Resembled a comet or rocket with halo and tail, and a cloudy appearance round it. Burst into two bright star-like appearances at last; followed shortly by a long low peal of thunder.	T. Brockway. 'Chronicle' of the London Missionary Society, 1877; (communicated by H. Corder).
7°	Horizontally from N. to S.; radiant in Cassiopeia (?)	Ended with a flash, and small terminal spark. Left an orange streak for 2 or 3 seconds.	H. Corder.
....	Radiant S. 5, 6, in Virgo; [confirmed generally by the Bristol observation.]	Flickered in transit; light dimmed by twilight. [Also seen at Bristol; see these Reports, vol. for 1877, p. 122.]	W. H. Wood.
8°	Downwards, left to right; inclined 45° from vertical.	Seen in twilight; left no streak.	J. E. Clark.
....	From direction of Pegasus...	Left a streak........................	H. Corder.
....	Apparently not a Perseïd. [Agrees with Denning's new radiant for August 10–13, at 97°+71°.]	Left a streak for 20 or 30 seconds. Similar meteors at $2^h\ 8^m$ (8° N.E. from Polaris) and $2^h\ 27^m$ a.m. (behind clouds in N.E.) lit up the sky like this one.	Id.
About 15° ...	....	Nucleus a large round ball, with another smaller body (one observer remarked) following in its track; also noticed in the north of London, see the 'Standard' of August 20, 1877.	James L. McCance. 'The Observatory,' vol. i. p. 177, Sept., 1877.
....	....	Pale coloured nucleus with a long trail of light emitting sparks of ruddy hue. Appearance very different from that of the Perseïd shooting stars.	Chelmsford Newspaper (communicated by H. Corder).
....	....	....	Communicated by G. J. Symons.
Not more than ½°	In the course of a few seconds afterwards three meteors (and a fourth some minutes later), equal to 1st mag. stars, appeared almost without motion at the same place.	Observer's attention attracted by the light in the sky; increased in brightness till it disappeared.	John Graham. Letter from D. Kirkwood in the 'Scientific American;' ('London Iron Trade Exchange,' Oct. 6).

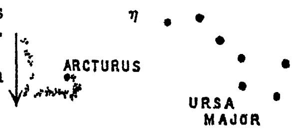
A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size.	Colour	Duration	Position or Apparent Path
1877. Sep. 11	h m s (About 8 0 p.m. Swiss; or 7 40 p.m. Paris time).	Petit Saconnex, near Geneva.	Large bolide	Pale green ...	About 3 seconds.	Beginning in the north-east, it passed from thence across the planet Mars, and disappeared in the south before reaching the summit of Mont Saléve.
11	(About 7 45 p.m.)	Boën, Loire, France.	Extremely brilliant fireball.	....	....	Moved at a small altitude above the eastern horizon.
11	(8 7 p.m. Swiss; or 7 46 p.m. Paris time).	Rossinière, Vaud, Switzerland.	"Nearly or quite as brilliant as that of Aug. 25, 1877;" [no other description of this "previous" large fireball given.]	....	Travelled rapidly.	Began just above [? below] η Andromedæ, and close by γ Pegasi to τ Aquarii, where it burst.
16	9 33 p.m.	Birmingham ...	= ♃	White	1·5 second ...	From α Arietis to μ Ceti.
28	About 7 30 p.m.	Höier, Tönder, Germany.	Apparent size of the full moon.	Red, then white.	Rapid	Shot upwards, crossing the zenith from no great altitude in the S.E.; and passing about 5° N. of ζ, disappeared near α Ursæ majoris (Mizar and Dubhe).
Oct. 2	8 59 p.m.	Bristol	= 1st. mag. * for $\frac{3}{4}$ of its course; then, with a flash, > ♀.	Very bright white.	Rather slow motion.	From $\frac{1}{2}$ (α β) Cephei, towards, and a degree past α Andromedæ.
2	9 46 p.m.	Ibid.	= ♃	Bright white.	....	At a low altitude in the N.N.W.
3	8 38 p.m.	Ibid.	= ♀	....	Very swift ...	A few degrees to the right of α and β Ursæ majoris.

THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
Traversed a large arc of the sky.	[About N. to S.]	The nucleus appeared spherical, brighter on its southern than on its northern side; died out, leaving a light-streak visible for a few seconds.	Geneva Newspaper.
....	Direction of motion from N. to S. Path sensibly curved.	Left a streak like that of a rocket on its path. A slight noise was heard during its passage by more than one observer.	V. Duram. 'Comptes Rendus,' vol. lxxxv, p. 577, Sept. 17th, 1877.
....	....	The nucleus threw out smaller bodies, like the fire-ball of Aug. 25th, on its course. Left a light-streak for 11 minutes, falling at the ends to a perfect bow-shape before disappearing. Shooting stars were frequent there and the sky was very clear.	M. F. Ward. (Communicated by G. J. Symons.)
....	....	....	W. H. Wood.
....	[Probable radiant in, or southward from Aquila, (or ? from Cygnus)].	First aspect like the full moon, but redder; shone out as it passed Mizar with a light like the sun's; and from there to near Dubhe left a light-streak 15° long, visible at the bursting-place for $1\frac{1}{4}$ hour; became S shaped and drifted westwards, the end-patch to η Ursæ, where it was hid by clouds. No explosion heard.	Towald Köhl. German Monthly Journal, 'Gæa,' vol. for 1877, p. 793.
24°	This meteor and the next were from a radiant of 7 or 8 bright shooting stars seen in 5 hours on the same night, in Quadrans, at 225° + 52°.	At its point of maximum or explosion, a short nebulous light streak remained visible $3\frac{1}{2}$ minutes, drifting 5° towards Cassiopeia before fading out.	W. F. Denning.
....	From the same radiant as the last.	A meteor = 1st mag. *, at $11^h\ 17^m$ was also directed from this point (near η Ursæ majoris); short course, with sparks, in Quadrans.	Id.
Short path ...	Directed from Polaris; radiant (from several meteors of the same and previous nights), 165° + 77°, between the Pointers and Polaris.	Left a bright streak on its path, 2° long., visible for 15 seconds in a very hazy sky.	Id.

A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1877. Oct. 8 (?)	h m 7 0 p.m.	Clermont Ferrand, Clermont, France.	> ♃, but < ♀..	Colour distinctly green.	Less than 2 seconds.	Began near α Ursæ majoris, and descended to the horizon.
8 (?)	7 0 p.m.	Tiffanges, Vendée, France.	Extremely bright meteor.	....	....	Just below the stars of Ursa major.
8	11 50 p.m.	Bristol	Meteor with bright flash = 2 × ♀	....	....	A few degrees above the E. horizon; from 109° + 17° to 116° + 12°.
19	Precisely 6 15 p.m.	Monmouth, Wales. [Similar descriptions at Cullompton, Bath, Hungerford, Strandtown, and Omagh, in Ireland, &c., contain no more exact particulars.]	Extremely brilliant meteor in strong twilight and moonlight (Arcturus plainly visible). [At Cork it illuminated the whole city.]	White; the streak for 20 seconds a dazzlingly white wand; then gradually growing fainter.	.... 	....
29	8 1 30	Dunecht Observatory, Aberdeen, Scotland.	A very brilliant meteor.	....	....	Point of explosion, and of the persistent streak at 268° + 60° (equinox of 1855).
30	....	St. Lawrence, Kent.	Brilliant meteor..	....	....	....
Nov. 4	8 4 p.m.	Birmingham ...	> ♀	Bright yellow [and red].	2·5 seconds...	From 350° − 1° to 327° − 17°.
4	10 13 p.m.	Sunderland ...	About = ♀.........	Deep orange.	About 1 second; quick.	From ½ (20 Ceti, δ Piscium) to ½ (Mars, ψ Aquarii) starting a few degrees before the former point.
7	9 4 p.m.	York	A fine meteor = ♂; brightness uniform.	Fiery red ...	$2\frac{1}{2}$ seconds; moved slowly.	From 100° + 59° to 190° + 51°.
14	3 23 a.m.	Sunderland ...	= ♃..................	Orange	1·4 second ...	From 47° + 27° to 24° + 17°.
16	6 21 p.m.	Ibid.	At least = ♃	Yellowish, and greenish; at last orange.	Very slow, 3 seconds.	From 270° + 16° to 255° + 16°·5.

THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
....	[Radiant from these two observations in R.A. 35°, and Decl. between + 5° and + 35°, approximately.]	This and the next meteor are identical, and the first of more than one seen on the same night in France.	M. Hugon. 'Bulletin de l'Association Scientifique de France,' vol. xxi. p. 224, Jan. 6th, 1878.
....	Moving towards the East ...	Burst with sparks of various colours.	P. Gustin. Ibid.
....	Conformable to a radiant point at 77° + 31° of 5 meteors seen on the same evening.	Left a streak 4° long. visible for 3 seconds.	W. F. Denning.
Fell some degrees.	Fell quite vertically till hid by a cloud-bank at a point $\frac{3}{2}$(η Ursæ majoris, Arcturus), as in the sketch. [The meteor at 5^h p.m., Oct. 18th (see Nov. 23rd, Note to the Hertford account) though quite similar, was yet, no doubt, a separate and earlier meteor.]	The streak curved gradually northwards, and drifted for 8 minutes until it lay almost horizontal (see the sketch); clouds then rising upwards obscured it. [The length of the 'spear' or 'comet' (end cloud and streak together) at Dublin, was '5 lunar diameters,' and its altitude above the horizon there 'about 50°.' See discussion of the meteor's real course in this Appendix.]	W. Watkins Old. (Communicated by W. F. Denning.)
Length of streak scarcely $\frac{1}{2}$°.	Streak directed towards ξ Draconis; streak and the meteor's course both foreshortened near the radiant point.	Left a short crooked streak on its track for 10 seconds. Though not itself visible to him directly, the meteor's flash was yet seen by Mr. Lohse.	Ralph Copeland. 'Nature,' vol. xvii, p. 29.
....	....	Its course and appearance were obscured by clouds.	Communicated by G. J. Symons.
....	Radiant R_3 in Musca. [Oct. 31st—Nov. 1st, 1877, Denning; 46° + 26°.]	Anterior half of nucleus ruby red; tail white, 15° long.	W. H. Wood.
....	? a Leonid; too swift for a Taurid. [Muscid; same radiant, R_3, as the last meteor.]	Left a blue or green streak on nearly its whole course for 2 seconds; not so bright compared to the head as those of the Leonids.	T. W. Backhouse.
20°	....	Left no streak. Fifteen other meteors were noted on the same night.	G. A. Walpole, 'Natural History Journal,' vol. i, p. 152, Dec. 15th, 1877.
21°	Leonid. [Directed nearly from λ, κ and η Leonis.]	Ended with a flash, and with a green streak there for 3 seconds.	T. W. Backhouse.
14°	Directed from ϵ Aquilæ. [From unknown radiant in Aquila or Aquarius (?).]	Brightest in mid-course; faded gradually; left no streak.	Id.

A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation.	Apparent Size	Colour	Duration	Position or Apparent Path
1877. Nov. 16	h m s 9 14 p.m.	York	= ♀	Blue	$2\frac{1}{2}$ seconds, very slow speed.	From 80° + 87° to 210° + 48°; course slightly curved.
16	9 14 10 p.m.	Ibid.	= ♀	Blue	Slow motion; about $1\frac{1}{2}$ second.	From 273° + 38° to 256° + 20°.
16	9 14 p.m.	Ackworth, Yorkshire.	= ♃ or ♀	Bluish	....	From Ursa Major across the zenith to α Lyræ. Path curved.
16	9 14 10 p.m.	Ibid	= ♃	Bluish	3 seconds ...	Began near α Cephei, passed within 1° of α Lyræ, and disappeared near η Herculis.
23	(Afternoon)	Richmond (and the States of Virginia, and N. Carolina, U.S.)	Fireball of the largest size; detonating.	....	....	....
23	About 8 25 p.m.	Llandulas, N. Wales	$\frac{1}{3}$ or $\frac{1}{6}$ diam. of the full moon. A $\frac{1}{4}$ in. magnesium tape produced by experiment the same illumination 4 ft. from the ground.	Bluish white, with train of red stars. The moonlight faded and colours of flowers showed clearly in its light.	$1\frac{1}{2}$ or 3 seconds (two estimates.)	Seen in the last part of its path to pass between β and γ, and between ζ and η Draconis, and to disappear below Draco. The first half of its course must have been from near Auriga.
23	About 8 25 p.m.	York; [and Mr. Crossley's Observatory, Bremerside, Halifax]	[In most accounts the breadth of the head was not less than, or even half as large again as the moon's diameter, with considerable elongation towards the tail.]	[Blue, green, white or yellow, and red. The colours of the fragments especially into which the meteor burst were very vivid.]	....	From 352° + 22° to 295° + 7°; end well seen at 1° below and 1° beyond α Aquilæ; beginning of the track marked by the light-streak pointing back to middle of the square of Pegasus, as the first appearance.
23	8 26 p.m.	2 miles N. of Hertford.	Two maxima, the first at π Herculis and the next	....	....	In the last 15° of its path seen to pass π Herculis

THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
45°	[Radiant, if common to both meteors, at 35° + 36°, Triangulum.]	Nucleus with a short tail of sparks. This and the next were two perfectly similar meteors; but not from the same radiant point [?].	E. Pickard. (Communicated by J. E. Clark.)
20°	....	Nucleus with a short tail of sparks; appeared 10 seconds after the last meteor.	Id. Do. 
Long path ...	....	[The course, as roughly stated, is almost the exact opposite of that described at York !]	E. Catchpool. (Communicated by J. E. Clark.)
20°	Course, serpentine or wavy...	Appeared far brighter than Vega Lyræ, when passing it. [The other two stars form with Vega a large triangle which is nearly right-angled at α Lyræ !]	Id. (These four descriptions are in the 'Nat. Hist. Journal of Societies in Friends' Schools,' vol. i, p. 152.)
....	Real course 8° or 10° W. of N.	Exploded over the S.E. corner of Halifax County, 15 or 20 miles W., a little S. from Clarksville, Va.	Memoir on the Meteor by J. L. Campbell, in the 'Scientific American,' vol iii. p. 2, 1878.
About 30° while in sight.	The direction only well observed in the last part of its flight.	The head was circular in outline, followed by a tail of red stars, estimated at between 10° and 15° in length. After a lapse of between 5^m and 10^m a loud distant explosion, lasting about 1 second, came from the West.	Dr. Grimesdale, and Richard Caton. (Communicated by R. P. Greg.) Fuller descriptions and discussions of this large meteor are elsewhere given in this Appendix.
3° or 4° in sight; green and red; breadth $\frac{2}{3}$, length = 1 diam. of the moon.	[The same direction of its course ("from square of Pegasus to near Altair") was noted at Rotherham, near Sheffield, by Dr. S. Drew; bluish green, globular, then elongated, ruddy, with tail. Slow; no sound of bursting; ('Nature,' vol. xvii. p. 94).]	[The equatorial room filled with green light; turning to the west window, saw the fragments of the explosion falling in the sky, the colours of their streaks of light being red and green. At 4^h 10^m p.m., Nov. 22nd, a very vivid flash of (?) lightning made an open book look quite green.]	E. Pickard and A. Pumphrey. 'Natural History Journal,' vol. i. p. 153, Dec., 1877. [Joseph Gledhill.]
....	Fell vertically. [Like a fine shooting star at first, but suddenly enlarged, as if	The slight light-track or trail left, vanished immediately. [An account of its appearance	F. A. Buxton, 'Nature,' vol. xvii. p. 94; Nov. 29th, 1877.

A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1877.	h m		at termination. Estimated diameters would be illusory from its prodigious brightness.			to a point of sudden disappearance above the horizon, at 250° + 30°.
Nov. 27	10 26 p.m.	The Royal Observatory, Greenwich.	= ♀ in the third quarter of its course, growing fainter thence to disappearance.	White or blue; and at last dull red.	Duration not less than 15 or 20 seconds, fairly counted.	From 6° above Castor to a point 5° to the left of Sirius.
27	10 25 p.m.	Writtle, near Chelmsford, Essex.	= to a 1st mag. * at appearance; = ♀ at disappearance.	Red at first, then greenish blue.	Part of path seen, 6 or 8 seconds.	From 79° + 34° to 91° − 1°; and from other accounts continued several degrees.
Dec. 2	About 8 15 p.m.	St. John's, Devonport.	A splendid meteor	....	....	Position of its course from S. to W.
2	8 15 p.m.	Babbacombe ...	Large meteor......	Green, changing to violet.	....	Fell from 15° to 5° above the S.W. horizon.
7	5 38 p.m.	Sunderland ...	= ♃	Bright green; short train of bright red sparks.	Moderately quick.	Disappeared (behind a house) at 197° + 35°.
8	6 23 p.m.	Writtle, near Chelmsford, Essex.	= ♀	Pale green	4 or 5 seconds	From 48° + 2° to 55° − 10°
9	8 13 p.m.	Ibid.	= ♃ in the last part of its course; less bright at appearance.	Bluish mauve	4 seconds ...	From 285° + 70° to 289° + 30°
9	8 13 p.m. (± 2ᵐ).	Bromley, Kent. N. lat. 51° 24′¾, E. long. 2′¼.	8 (± 2) × α Lyræ	Emerald green; streak yellow.	1·6 (± 0·3) second.'	Shot from 32 Camelopardi (± 1°) across μ Lyræ (± 1°), and disappeared about 6° beyond.
9	11 36 p.m.	Writtle, near Chelmsford, Essex.	= Sirius	Pale emerald green.	0·5 second ...	From 135° + 27° to 147° + 22°
9	11 58 p.m.	Ibid	= Sirius	Pale mauve...	1½ second ...	From 120° + 75° to 250° + 91°
15	About 7 p.m.	Southend-on-Sea, Essex.	Large luminous body.	....	3 seconds ...	Passed from S.E. to N.W.

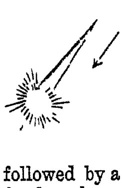
THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
	plunging into "fiery elements" and drawn by them to the earth, then it first melted to a drop, and a second time broke into fragments as it disappeared. (Writer in the 'Manchester City News,' Feb. 23rd, 1878.)]	at Cathedine, Brecknockshire, states that in the previous month at 5h p.m. on Oct. 18th, a beautiful meteor, "like the evening-star setting rapidly," fell in the West; and its glow remained there when the meteor set behind the Alt. 'The Times,' Nov. 27th.]	[At that page and at p. 114 there are numberless accounts; finally also of a detonating meteor at Strasburg, at 6 p.m. on the same night.]
....	....	Moved, especially towards the end, with extreme slowness.	G. L. Tupman. 'The Times,' Dec. 3rd, 1878.
More than 40°	Directed from Lyra	Nucleus followed by a red train; faded rapidly after reaching its greatest brilliancy.	H. Corder.
....	....	....	Communicated by G. J. Symons.
....	....	It exploded twice, giving off orange sparks.	Id.
....	Directed from about $\frac{3}{8}$ (β, ψ) Ursæ Majoris.	A part only of its course was seen; the point of disappearance accurate within 1° or 2°.	T. W. Backhouse.
13°	Radiant in Triangulum (?)...	Nucleus with a slight train; flashed out several times; but seen in haze and behind trees.	H. Corder.
40°	Radiant at ι δ Geminorum ...	Left a streak; position not very accurately mapped.	Id.
....	....	A brilliant meteor; left a streak visible for 1 second. [Identical with the last meteor.]	W. M. F. P. 'Nature,' vol. xvii. p. 124. Dec. 13th, 1877.
10°	Geminid	Left a streak........	H. Corder.
20°	Radiant at ι δ Geminorum ...	Left a streak; path not accurately mapped.	Id.
....	....	Though veiled behind cloud and haze, it appeared extremely large.	Newspaper paragraph.

A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1878. Jan. 10	h m s 10 36 20 p.m.	London (3 miles N. of St. Paul's).	As bright as, and 2 × diam. of ♃ "then in the field" [?].	....	....	Occulted δ Cassiopeiæ lying on the cross wires.
13	(4 24 p.m.)	Salthill, between Kingstown and Dublin.	Very bright meteor.	Tail and globe of explosion light blue.	....	In the north-west, at an altitude of about 10° or 15°; a distant fireball, probably over the West Coast of Ireland.
31	4 56 a.m.	York	About $\frac{1}{10}$ diameter of the moon, and as bright as Sirius.	Bluish green	4 seconds ...	From 50° W. of S. to 10° E. of S.; altitude about 10° or a little more; too low down for comparison with any neighbouring fixed stars.
Feb. 17	(7 53 p.m.)	New York, U.S. America.	Brighter than Venus.	White	3 seconds. Moved slowly.	Passed a few degrees below Mars, moving south-easterly towards Canopus.
18	(12 47 a.m.)	Dublin, in the east part of the town.	About $\frac{1}{5}$ diameter of, and more luminous than the moon.	Bluish white, train yellowish.	....	Began in Draco, 15° from Polaris, a little below a point at $\frac{1}{2}$ (Polaris, α Lyræ), and disappeared when at an altitude of about 10° from the horizon, in the north.
March 15	(About 8 30 p.m.)	Lahore, India...	As bright as the full moon.	....	....	Passed over the town and exploded to the westward.
25	About 10 15 a.m.	Wigton, Dumfriesshire, Scotland.	Large; dazzling, even in sunlight.	....	About 4 seconds.	From an apparent altitude of about 50° in the S.E. to the crest of a mountain ridge; altitude about 25° in the east.
25	10 17 a.m. [10 20 a.m.]	Clitheroe, Lancashire [and Hawick, Roxburghshire].	At least equal in area to half a full moon: and in brightness 10	....	....	A little to the east of north. [Seen, near its disappearance. in the

THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
$1\frac{1}{2}°$ of its path seen in the field of view.	Directed nearly towards γ Cephei; 19° from horizontal, from W. to E.	Seen in the finder of an altazimuth telescope, magnifying 15 times.	E. Catchpool. 'Natural History Journal,' vol. ii. p. 11.
....	Inclined about 10° from vertical towards the south.	Nucleus with tail 5° or 6° in length, and globe of some size, when bursting.	O. W. Reilly. 'Nature,' vol. xvii. p. 221.
....	Travelled almost horizontally. Path slightly curved.	A fine bolide. Nucleus globular, without tail; went out without explosion.	'Natural History Journal,' vol. ii. p. 11.
About 30° ...	Directed from Andromeda ...	Nucleus followed by sparks for 1° or 2° behind it; showed an apparently spiral movement.	Paragraph in the 'Scientific American' of Feb. 23rd, 1878, (communicated by J. E. Clark.)
....	About 5° inclined from vertical, descending from left to right.	A ball of light, leaving a continuous luminous train; no explosion seen, or sound heard; passed behind houses. Its light surpassed that of the moon, which was then strong enough for reading print.	H. Hatfield. 'Nature,' vol. xvii. p. 342, Feb. 28th, 1878.
....	....	Unusually large fireball; burst, scattering fragments in all directions with a report like thunder.	The 'Homeward Mail,' April 8th, 1878.
....	Descending there at a slope of about 45° from vertical (see the sketch).	.... 	J. E. Walker. (Communicated by J. E. Clark.)
....	Descending perpendicularly. [Descending with an inclination of about 40° to the horizon.]	Nucleus followed by a train 5° or 6° in length. A grand meteor, even in the brilliant sunlight. [In bright sun-	W. Garnett. The 'Manchester Guardian,' March 28th, 1878.

A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1878.	h m		times more intense.			east, descending towards the north point of the horizon.]
Mar. 25	10 20 a.m. [10 23 a.m.]	Newcastle-on-Tyne [and Darlington, Yorkshire].	Meteor with large apparent disc.	Body and tail white, or yellow, purple-edged.	$1\frac{1}{2}$ or 2 seconds while in sight.	From alt. about 10° to alt. 2° or 3° (to the horizon), between 7° (Walbottle), and 12° (Little Benton), E. of true north (two measurements). [From alt. about 25° to alt. about 10°, N.N.E. estimated.]
25	10 22 a.m. (Exact railway time.)	Coupar-Angus Railway Station, Perthshire.	Bright enough to attract attention of all persons looking eastwards.	....	....	From near the sun's apparent place (alt. 32°, 30° E. from S.) to alt. $11\frac{1}{2}$°, one point N. of magnetic east (due N.E. by E.; measured point of disappearance by top of a signal post).
25	About 10 26 p.m.	Callander, and Pass of Leny, Perthshire. [For other views of the meteor in Scotland, see the general account in this Appendix.]	Length of the cone $1\frac{1}{2}$ or 2 diameters of the moon; [about three times as great as its breadth; at Lennoxtown: round in front, tapering to a point behind.]	White; with a violet halo, merging outwards into crimson, round it.	About $1\frac{1}{2}$ sec (in brightest part of its flight).	From alt. 16° or 18° E.S.E. (first appearance), to a point of first scintillation about E. by N., and of disappearance at alt. 8° or 9°, 30° N. of E., behind a hill (measured path from two descriptions.)
April 2	A few minutes before 8 0 p.m.	(No place recorded.)	3 or 4 × ♃	Silvery white changing to pale red.	Rather slow speed.	Started [or? took its direction] from Ursa Major; and remaining stationary a second or two between Orion's belt and Sirius, fell thence to the horizon.

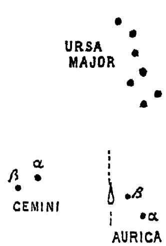
THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
		shine; followed by a tail. Jas. Elliott, 'Nature,' March 28th.]	
[20° or 25°, estimated.]	Slope of path 10° from vertical, thus (Walbottle):— 10°  [Fell vertically.]	Other notes of its appearance at and near Newcastle ('Nature,' vol. xvii. p. 466), by Mr. T. P. Barkas, agree with these.  [Appearance at Darlington.]	W. Clark; J. A. Woods. (Communicated by A. S. Herschel.) [A. Backhouse; communicated by T. W. Backhouse.]
....	The streak began east of, and was directed nearly from the sun's place. The meteor itself not seen, but described to the observer.	Head conical; left a cloud streak 20′ broad, sharp-edged, and quite straight for two minutes, on nearly its whole track, which then curled up into separate wisps along it, and grew diffuse; no dense parts in it; nor report heard.	J. Robertson. (Communicated by A. S. Herschel.)
....	Direction of the course towards the N.E. ½ N. point of the horizon; inclination there about 20° (a close average of two independent measurements).	Aspect a cone of fire, of electrical brilliancy, dwindling behind to a tail; the latter visible some moments after the nucleus had disappeared behind a hill; some sparks, but no cloud streak observed.	J. B. Hamilton. ('The Scotsman,' March 27th), and W. McDougall. (Communicated by A. S. Herschel.)
....	Fell vertically ("in a direct line to the horizon").	Nucleus pear-shaped. Grew red as it approached the horizon, where it disappeared behind a cloud leaving a long track of light behind it.	'The Times,' April 4th, 1878.

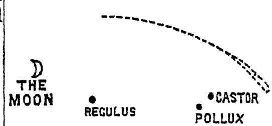
A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1878. April 2	h m 7 52 p.m. or 7 53 p.m.	Birmingham ...	About ½ diameter of full moon.	At first bluish; then burst into red fragments.	5 or 6 seconds, moved very slowly.	Travelled the middle half of the distance between Ursa Major and Leo (from 176° + 41° to 176° + 24°, by a sketch of the track among the stars.)
2	About 7 55 p.m.	Leicester	About ¼ diameter of the moon; cast the observers' shadows like the moon.	Yellow or orange.	....	Shot from 5° E. of α towards, and nearly as far as, ζ Orionis (observed part of the path.)
15	7 30 p.m.	Bolton, Lancashire.	A fine meteor ...	....	....	In the north-east.
May 12	About 8 50 p.m.	Derby	Fine meteor with well-defined disc.	....	....	Started from the constellation of the Lesser Bear [?]. Disappeared behind dense clouds near the N.N.W. horizon.
12	8 53 p.m.	York	Almost as bright as ♀.	Brilliant white, or yellowish.	6 seconds; and light seen two or three seconds earlier.	Passed 9° or 10° to the right of Capella, from 10° above it in altitude to alt. about 9° or 10° in the same azimuth.
12	8 51 p.m.	Scarborough, Yorkshire, (and Preston, Lancashire.)	Large fireball ...	Bright white; tail reddish	Very slow passage; several seconds in sight. (Slow speed; 5 or 6 seconds).	From near the southern part of Ursa Major, shot about 5° left of β, and 10° left of α Aurigæ to behind house roofs (alt. about 10°) in the north-west.
12	About 8 53 p.m.	Whitby (and Wakefield), Yorkshire.	(An incandescent body of some bulk.)	(Very bright white; the chain of fire following it	5 or 6 seconds.	....

THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
17°	[Radiant-point, by a projection of the Birmingham and Leicester tracks, 177° + 46°, in Ursa Major.]	Light of the meteor like that of full moon overhead. Burst into fragments at last.	T. Barclay. 'Natural History Journal,' vol. ii. p. 65, June, 1878.
....	Fell almost perpendicularly; course slightly zigzag.	Nucleus with short tail; left no streak. Three minutes after disappearance a report like distant thunder followed from its direction.	F. T. Mott. 'Nature,' vol. xvii. p. 466.
....	N.W. to S.E.	Soon after sunset; in strong daylight.	A. Greg. (Communicated by R. P. Greg.)
....	....	Twilight still very bright and no stars visible.	'Derbyshire Advertiser and Journal,' May 17th, 1878.
24° while in sight.	Fell quite vertically; azimuth 36° W. of true N. by a compass, agreeing with the azimuth by Capella.	Noted (through window panes) by several observers called in time to see it. No streak or sparks; but split at last into two, one fragment $\frac{1}{4}$° behind the other, when both went out, or passed behind low clouds.	W. T. Jackson. (Communicated by J. E. Clark.)
(Almost due north, descending obliquely, E. to W., from about alt. 60° to alt. 15°.)	.... 	Nucleus bright white, even in the northern twilight; with a short reddish tail (followed by a tail 3° long., which ceased when the meteor broke, near the end of its course, into several pieces, and soon after disappeared).	A. Rowntree; communicated by J. E. Clark (correspondent of 'Nature,' vol. xviii, p. 77, May 16, 1878).
(From a great alt., a little S. of West, to a point of the horizon	....	Nucleus with not much tail, double headed (see the sketch); let fall a piece like a red-hot cinder just before going out, or passing behind	J. T. Sewell. (Communicated by J. E. Clark.) (H. S. M. the 'Yorkshire Post,' May 15th, 1878.)

A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1878.	h m s					
				glowed at times with purple and emerald hues.)	Sketch of the meteor's course. 	
May 12	About 8 55 p.m.	Kirknewton, (and other places in or near) Edinburgh. [See also the apparent path at Bathgate described in the general account of the meteor in this Appendix.]	($\frac{1}{6}$ the apparent size of the moon.)	Fine violet colour. (Front part white; rear and tail of sparks red)	(5 or 6 seconds.)	From about alt. 50°, 30° E. of the moon, passed a little W. of the zenith to alt. about 50° or 60° N. W. by N. from the zenith (the angles measured with two pencils held across each other; the compass bearings not quite so certain).
12	About 9 p.m.	Galashiels (and Stonykirk, 5 miles S. of Stranraer), Scotland.	Large meteor. (Large and beautiful; same appearance as at Edinburgh.)	....	5 or 6 seconds in view.	Passed along the valley to the N.N.W. (General position of its path directly over New Galloway.)
12	(About 9 45 p.m.)	Geneva, Switzerland.	Large fireball.	....	....	....
27	(7 30 p.m.)	2 miles S.W. of Funchal, Madeira.	10 or 15 × ♀. More brilliant in the twilight than ♀ appears at night.	Head brilliant green; in striking contrast with the tail, bright red.	Motion moderately fast.	Began at alt 25° or 28°, N.E. by E., and passed to a point behind some trees at alt. 20°, about due N. (Altitudes estimated by the polar star.)

THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
over Middlesborough and Durham, about 40° W. of north.)	 Shape of the head.  Do. when the red particle separated from it. (From midway between the horizon and the zenith to a point very near the horizon over Otley.)	a cloud. [Fell vertically, due N., at Calne, Wiltshire, and in London; 'The Times' and 'Nature,' May 16th; and slowly in the N.N.W. at Manchester. (R. P. Greg).]	
....	(At first horizontal; and at last descending towards the direction of Fettes College and Corstorphine Hill.)	Oblong, giving off sparks in irregular outline, and leaving a trail of stars behind it; then burst into pieces, and disappeared. (Nucleus followed by a tail of red sparks or 'cinders,' about ten times the head's diameter in length; the whole forming an elongated firebolt.)	D. R. Stewart. 'Nature, vol. xviii, p. 77, May 16, 1878. ('Astrologer,' 'T.R.,' 'The Scotsman,' May 15th and 16th, 1878.)
....	....	Head a round ball of electricity. Tail long and tapered, of the same brightness as the head; both at last melted away. Two minutes after disappearance one loud deep peal of thunder heard; sheet lightning began a quarter of an hour later, and continued to flash for some time.	J. S. (and J. D.). 'The Scotsman,' May 16th (and 20th), 1878.
....	....	[Corresponding in time of appearance to about 9^h 20^m p.m. G.M.T.]	'Nature,' May 23rd, 1878.
....	Somewhat descending, in a path slightly concave to the horizon.	Head a round ball, thirty or forty times more bright than α Lyræ (?), a star seen just below it among clouds; followed by a rocket-like tail of sparks, which was not persistent; no report heard.	W. A. Sanford. 'Nature,' vol. xviii. p. 169, June 13, 1878.

A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1878 June 6	h m 9 25 p.m.	Cambridge, Massachusetts, U.S.A.	Fireball, with sensible disc; very brilliant.	Crimson in front, like a strontian flame; tail and rear part of the nucleus bluish violet.	5 or 6 seconds in sight; burst in 3 or 4 seconds	In the northern sky; began at o Ursæ Majoris, and passed through an hour angle [? azimuth] of at least 1^h 30^m.
7	About 5 15 p.m. or 5 20 p.m.	Bristol, and neighbouring places.	A large fireball ...	....	....	No good descriptions of the apparent path preserved.
7	8 30 p.m.	Clifton [and Bathwick; and Ridland Green (? Bristol)].	Large meteor. [Large and splendid even in the nearly broad daylight (Bristol ?).]	[Bright blue.—Head luminous with pale green tinge (Bristol ?).]	6 or 7 seconds or more; exceedingly slow motion.	Descended from near the zenith, alt. 50° or 60° N.N.E. northwards, disappearing in haze near the N. or N. W. horizon, about alt. 10° N.N.W. Magnetic bearings taken with a compass.
7	9 45 p.m.	Glastonbury, Somersetshire	Fireball with a large disc.	Pale blue ...	20 seconds, moved rapidly.	....
7	9 52 p.m.	Knole Park (Kent), near London, [and Cheltenham, &c.]	Brighter than the moon in its first quarter.	Very pale green, like a glow-worm's light.	[Time of flight about 20 seconds; slow and majestic.]	Began 5° from, and passed 3° below the moon (reckoning its diameter at ½° roughly) and disappeared about 20° further northwards
7	About 9 50 or 9 55 p.m.	Bristol, [and Bathwick.]	> ♃; about ½ diameter of the moon.	[Exhibited most brilliant green, purple, and gold rays.]	Motion slow and gradual	From slightly below α Libræ to slightly above α Leonis, passing about 1° above Spica (α) Virginis, and 6° above the moon [164° + 4°; alt. 21½°, 23° S. of W.]
7	9 52 p.m.	Hawkhurst, Kent, (and Brompton Road, London).	Large fireball; light equal to the moon's.	(Head or fore-part bright green, like nickel sulphate; tail	After watching it a moment counted 34 not very	From alt. 9° or 10° due S.W., to almost exactly the same alt. about 20° N. of

THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
....	Its apparent course was about due west, [which *o* Ursæ Majoris was also from the N. Pole; not conformable to the radiant in Scorpius of the two next meteors.]	Nucleus egg-shaped, in length half as long again as its breadth, and smallest behind, with a long luminous train following it; the latter formed of several globules (five or six at least) in a row, the brightest near the head.	G. H. E. Trouvelot, 'The Science Observer' (Boston, U.S.), vol. i. p. 78.
....	....	Seen in daylight	Communicated by W. F. Denning.
... .	Descending from right to left, slope of path about 30° from vertical; positions by memory and measurement soon after. [From E. to W., appearing to strike the earth on or near Durdham Down (? Bristol).]	Nucleus pear-shaped; not undulating in its motion, nor emitting sparks, nor nearly so brilliant as that seen at about 9.45 p.m. on the same evening. [Like the later meteor, it had a long tail.—Like a globe of liquid and transparent fire (Bristol ?).]	Andrew Lighton. (Communicated by W. F. Denning.) [Captain Cunninghame; and G. Holmes; newspaper extracts.]
....	S.E. to N.W.	Nucleus round; emitted jets of large sparks as it moved along.	'Central Somersetshire Gazette.'
....	S. to N., very nearly parallel to the horizon, with a very slight declination towards the north. [Almost due E. to W.]	At first cast the observer's shadow like the moon, which looked a muddy yellow disc beside it; disappeared suddenly. [Like a Bengal light passing through the heavens.]	H. Middleton Rogers. 'The Times,' June 10th, 1878. [Ibid; seen also at Southampton, Tunbridge Wells, and Beckenham.]
Very long flight; about 70°.	From E. to W., almost horizontal and parallel with the ecliptic. From a radiant near Antares.	Nucleus pear-shaped, varying in brilliancy; casting off a short train of sparks as it sailed along; very fine even in strong twilight and moonlight. [Nucleus with tail of light behind it "ten yards" in length, "was seen for a few seconds after the tail had disappeared."]	W. F. Denning. 'The Times,' June 10th, 1878. [Captain Cunninghame; newspaper extract.]
....	Slowness, and horizontal direction of the motion was very remarkable. S. to N., roughly, descending slightly northwards. (S. to N.;	Nucleus with very little tail; but smoky atmosphere or cloud-haze round it. Disappeared without explosion, with a gradual extinction.	T. Humphrey. Communicated by A. S. Herschel. (L. J. Whalley, 'Nature,' vol. xviii. p. 185.)

A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1878.	h m s					
				or rear part of a red purplish hue.)	fast (7 or 8 seconds) while it was in sight.	W. Passing under the moon at about ¾ of its alt. in the early part of its flight, and grazing some house-roofs (positions measured) there and near its disappearance.
June 7	9 52 30 p.m.	Twickenham, Surrey, [and Prees, 14½ miles N. of Shrewsbury.]	Longer diameter of its figure about ⅓ of the diameter of the moon.	Bright emerald green; throwing a distinctly green light.	[4 seconds or more; colour greenish white.]	Shot from south-west to north-west, passing under the moon at alt. 14°, 69° W. from south. [First appeared in the south, and moved horizontally westwards.]
7	9 53 p.m.	Greenwich, Kent.	About the same size and brightness as the moon.	Centre of tail and nucleus pale orange, fringed with violet rays.	About 3 seconds in sight.	Grazing house-roofs in the west, passing 6° or 8° under the moon's lower edge.
7	9 53 p.m. [About 10 p.m. Paris time.]	Silverton Station, Devon; (Jersey); [Versailles, and Department of Aisne, France.]	(Rather more than ½ apparent diameter of full moon; and shining far more brightly. [Width, ⅙ diam. of the moon.]	First white or pale blue, then deep blue; and fragments after the explosion were blood-red. (A beautiful white light).	Moved slowly. (Altogether about 30 seconds.)	Shot towards Ursa Major, and exploded a little beyond that constellation. (First seen about 30° from the zenith nearly due N.; descended towards the horizon, disappearing there behind a high wall). [Travelling westwards at a small altitude.]
14	9 14 p.m.	Bristol	Nearly = ♀	Pearly white.	Slow motion.	Descended in the E. by S. (bearing of centre of path) from alt. 35° to alt. 8°. (Measured altitudes and bearing.)

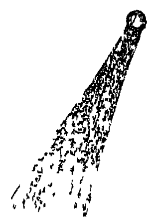
THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
	path declining a few degrees towards the horizon.)		
....	Path nearly parallel to the horizon, declining very slightly towards its disappearance.	Disapeared very suddenly. [Appearance near Shrewsbury; see the sketch. Broke into fragments of light.]	'Nature,' vol. xviii, p. 185, June 13th, 1878. [John Allen and E. Beckett. Communicated by W. F. Denning.]
....	Moved horizontally towards a point of the horizon about two points west of north.	Nucleus with tail six or seven diameters of the head in length; not a perfect cone, but winged or spreading at the end.	A correspondent of 'Nature,' ibid.
....	....	Burst at last into several fragments. (Nucleus round, leaving a very faint light-streak, and undergoing no explosion while in sight.) [Nucleus of extreme brightness, with tail about $2\frac{1}{2}°$ (four or five moon's diameters, in length.]	'Nature,' ibid.
....	Descending, from right to left, about 27° inclined to a vertical line.	A fine meteor seen in full twilight; no stars yet visible.	W. F. Denning.

A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1878. June 25	h m s 10 48 p.m. (Pretty accurate.)	Debenham	Breadth of the nucleus nearly the distance between Alcor and Mizar; of the end of the tail ½ or ⅔ diameter of the sun. Much brighter than Vega or Arcturus.	Reddish	Moved slowly	Began at a point forming a triangle towards the south, with β and ζ Cassiopeiæ; disappeared near 7 Lacertæ; (path and appearance of the meteor from a description.)
July 22	At night (between 11ʰ and 14ʰ).	= ♃; and nearly = ♀.	...	...	...	...
29	10 24 or 10 25 p.m.	Bradford (Hyde, &c.), near Manchester.	⅔ diam. of the moon (more luminous than any lime or electric light; making the smallest objects visible).	(The flashes white; the stars or fragments left, bright red.)	(Short duration.)	In the northern sky; began at an altitude of 50° or 65°. (The trail reached from the zenith in a north-easterly direction.)
29	10 25 p.m.	Styall; 11 miles nearly due S. from Manchester.	Sensible disc much larger and brighter than ♀.	Light of the flash very blue.	The whole illumination 1½ second. Pretty swift.	Passed through the centre of the square of Ursa Major, and when emerging from it, disappeared. The first and strongest flash probably in the head of Draco.
29	10 31 11 p.m.	Middleton, 5 miles nearly N. from Manchester.	Large; the flash like sheet lightning	...	From first flash to disappearance between 2 and 3 seconds.	Position of the persistent track from 278° + 48°, in Lyra, to 197° + 47° in Canes Venatici. An exact observation.
29	10 25 p.m.	Bristol (and Colwyn Bay, near Conway, N. Wales).	Most brilliant meteor. (Like light of day, of the electric, or limelight.)	Bright bluish white. (Bright bluish white.)	Motion not very rapid	Near the horizon, in thick haze, descending from the region of Cassiopeia. (In the northern sky, near Cassiopeia and Polaris).

THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
....	Ascended obliquely as in the sketch.	Head with a fan-shaped tail of sparks, as in the sketch. 	V. Cornish. (Communicated by W. F. Denning.)
....	The larger one, and two other meteors, from a very exact radiant-point in Quadrans, at 234° + 48°.	Two fine meteors, among twenty-five seen in three hours. Four or five Cassiopeiads, from about 10° + 52°.	W. F. Denning.
(Length of the trail fully ⅓ of the visible heavens.)	Descending obliquely eastwards, at an angle of 70° from horizontal. (In a slanting direction from west to east.)	A string of brilliant beads 15° in length formed its train, and vanished with it. (Burst into myriads of luminous red fragments. The flash double; a ball of lurid flame when disappearing, leaving a long trail along its track).]	R. Wilson. (J. R. Norman; 'Observer,' &c.) The 'Manchester Examiner and Times.'
5° or 6° of the end of path, only, seen.	Straight from the head of Draco, and from Lyra.	Not much trail or sparks visible more than 1 sec. after disappearance of the head. The first flash brighter than the light at last. Disappeared suddenly.	R. P. Greg.
....	....	The flash while observing Jupiter with a telescope. The meteor just glimpsed when disappearing; a track as marked as that of a rocket remained visible long enough to record its place exactly.	Thomas Kay. ('Manchester Examiner and Times,' July 31, 1876; communicated by R. P. Greg.)
....	Fell almost vertically. (From about S. by W. to N. by E.) 	The appearance something like the sketch; leaving no track on its path after the second burst of light. (A ball of fire with unusually long tail attached.)	Edward Barker. Communicated by W. F. Denning. ('Manchester Examiner and Times,' August 22.)

A LIST OF FIREBALLS SEEN DURING AND BEFORE

Date	Hour Approx. G.M.T., or (Lcl. Time)	Place of Observation	Apparent Size	Colour	Duration	Position or Apparent Path
1878. July 29	h m 10 25 p.m.	Whitehaven (and near Lancaster).	Large (lighting up the heavens, when first seen, to disappearance).	....	Illumination lasted a second or two.	Apparent position about due south (From a little east of the zenith, 10° or 15°, fell to a point at some altitude, about 30°, in the S.S.W.)
29	About 10 20 p.m.	Loweswater, Cockermouth, Cumberland.	Almost as large as the sun's disc at noon.	White	Moved very rapidly.	Altitude about 55° or 60° [?]; due S., or a little E. of S. (Path ill-seen; positions not very satisfactory.)
30	1 44 a.m.	Bristol	Meteor with a flash = ♀.	....	....	Between Fomalhaut and δ Capricorni.

The meteor was seen at Manchester, and at many places in the north of England; but it was principally seen in Scotland, and most brilliantly in the neighbourhood of Dundee, as at Alyth, Arbroath, and other places in Perthshire and Forfarshire. Notes of its appearance at these places, and also at Dunbar and at Lennoxtown (near Glasgow), not noticed in the catalogue accompanying the Appendix, were recorded in the 'Scotsman' and 'Dundee Courier and Argus' of March 26th, and in the 'Blairgowrie Advertiser' of March 30th (as the Committee was apprised by Mr. John Robertson, of Coupar Angus), and in answer to its inquiries the Committee also learned of its having been seen near Tyndrum, and by the Scottish Meteorological Society's observer, Mr. G. Croucher, at Ochtertyre, near Crieff, in Perthshire. The description of the meteor's form and colour was substantially the same at all these points, being that of a cone, pointed behind and round in front, in length about three times its breadth; white or yellow in the centre, with a border of red light surrounding it. At Alyth, "it had a streamer about a yard long, and as it came between the observer and the sun it had a very imposing and grand appearance." Another observer describes it as "a fiery figure, shaped like an immense V, which [starting near the sun] flowed right east, with a brilliancy eclipsing the sun even, and then it burst into fragments." At Dunbar, the conical head of the meteor, rocket-like at first, was likened, as it slanted earthwards, "to an umbrella half-closed," bright flames seemed to issue from four points of the central body, which was yellow in the middle and bright red at the outer fringe. A long streak of light marked its track for 15 or 20 minutes, and a peal of distant thunder was heard about the time of its disappearance. At Dundee it burned and flashed in its descent like a rocket, and on apparently nearing

THE YEAR ENDING IN AUGUST, 1878—*continued.*

Length of Path	Direction or Radiant-point	Appearance, Remarks, &c.	Observer or Reference
....	Direction of its course [from ?] about north-east.	Burst, leaving a long trail of bright red atoms like rocket-stars for a considerable time.	John Kinrade. 'Manchester Examiner and Times,' August 3, 1872. (Communicated by R. P. Greg.)
Only the end of the course seen.	Course descending; inclined about 40° to the horizon from S. towards S.E. [??]	The tail merged imperceptibly into a long line of light, left visible for a minute on about 10° of the last part of the meteor's path.	J. E. Walker. 'Natural History Journal,' vol. i. p. 104, Sept. 1878.
Short course.	Directed from θ Aquarii	Dived down with a flash and disappeared.	W. F. Denning.

the earth it burst into a thousand fragments. The streak left on its track was likened at Ochtertyre, as the meteor descended a short distance in the N.E., to the "train of smoke left by a fast passenger train passing along." At Arbroath several observers noted it "as an enormous ball of fire passing rapidly before them. At length it exploded with magnificent effect, the fragments, as it were, remaining semi-enveloped in smoke for a few seconds." Though appearing (as at all these places) in bright sunshine it was yet seen by many there, and one observer at Arbroath, who only saw it burst, was yet, like others who noted its startling apparition at such an hour so struck by its descent in broad daylight as to be somewhat alarmed. The streak was long and straight at first, about $\frac{1}{3}$° wide, without any condensations (at Coupar Angus) for about two minutes, and only curled up into separate wreaths as it slowly disappeared. A light-train, 5° or 6° long, following it like a tail, was seen at the most distant stations, but no indications of the enduring cloud track nor of the explosion were noticed at a distance; and the only record of a distinctly audible report or detonation having apparently proceeded from the fireball is that of a distant peal of thunder, which was noted at about the time of its disappearance at Dunbar.

1878, April 2nd, 7^h 53^m p.m. A detonating fireball, Leicester and Birmingham.—The observations of the fireball's apparent path at these two places were very carefully recorded by the stars. When projected upon a single plane perspective chart of the sky for the observer's stations at the time of the meteor's appearance, they are found to be in excellent accordance with each other, although presenting an enormous parallax, or displacement of the apparent positions of the end point of the meteor's path in the heavens at the two stations. This angle between

the two observers' lines of sight of the meteor's point of disappearance is just 90°, or half of the visible span of the heavens, proceeding from a distance between the two observers' stations of only 35 miles. The meteor vanished accordingly at a height of only 14 miles above a point of the earth's surface, about three miles west of Coventry. The observations suffice also to determine completely the length and real position of the whole of the meteor's visible path, or line of flight, before reaching this point of explosion and of final disappearance. A complete view of the track was seen and mapped at Birmingham, extending to a length of 17°, which was traversed by the fireball in five or six seconds, so slowly, that it must certainly have been seen very much foreshortened, and have first come into view there very near its radiant point. Only the terminal part of the flight was observed at Leicester, but its direction prolonged backwards meets that of the Birmingham apparent path similarly produced, about 3° before the point of first appearance there, at a common radiant point of the two apparent courses in R.A. 177°, decl. + 46°, near χ Ursæ majoris. In April, 1872, several remarkably bright meteors were seen proceeding from radiant points in Ursa major (see these Reports, Vol. for 1872, pp. 104, 116), and the peculiar brightness of meteors belonging to a group of April showers with radiant points in that constellation was noticed by Mr. J. E. Clark ('Nature,' May 2nd, 1872); one of them was doubly observed at York, and at Hawkhurst on the night of the 19th of April, 1872, and its radiant point from the combined projection of the recorded paths was like that of the present fireball, close to χ Ursæ majoris. Heis' April-period radiant M8 (at 155° + 47°), with Schiaparelli's Nos. 52 and 56 at 163° + 47°, and 168° + 47° for April 10 and 14, together form a general region of divergence at the average place 162° + 47°, which is the last of three centres of the April 'Ursids' in Mr. Greg's general list of 1876 (Nos. 21 or 46, 45, and 56), and that to which attention was drawn by Mr. Clark, in his letter in 'Nature,' above noticed, as producing meteors of peculiar brightness. It is, however, the first of them, and especially Heis' radiant M7. April 1–15, at 180° + 49°, included in it, which agrees most nearly with the real direction of the present fireball's course.

With the real radiant point and point of disappearance of the fireball as thus established, and with its apparent place of commencement as seen at Birmingham, the beginning of its visible path is found to be at a height of 80 miles over the town of Beckingham, near Market Harborough. The length of its real course was 75 miles, descending steeply from an altitude of 58°, 4° N. of E., which was the direction of its radiant point; its time of flight was reckoned at Birmingham as about five or six seconds, giving, with the observed length of its course, a velocity of about 13½ miles per second as the fireball's real speed of flight. This is exactly the theoretical speed which corresponds, with the observed radiant point, to a parabolic form of the fireball's real orbit round the sun; this concluding result of the combined projections gives fresh assurance to the supposition that the fireball was really an unusually splendid and particularly brilliant member of an ordinary meteor shower.

At Birmingham the meteor's light was like that of the full moon overhead, attracting the observer's attention to its falling globe of bluish flame, and it burst into red fragments at disappearance. At a place not named (but apparently near Nottingham or Leicester), in the 'Times' of April 4th, 1878, where a rather more distant view of its appearance

seems to have been obtained (and where the meteor is also said to have descended from the direction of Ursa major), the nucleus or head is said to have been pear-shaped ending in a long tail of light; three or four times as bright as Jupiter, and bright white, changing to pale red as it approached the horizon. It moved slowly, and halted apparently for a moment in its course as it passed between Sirius and Orion's belt.

At Leicester, towards the close of its course, the width of the fireball's disc was about half the moon's diameter, and it was so radiant as to cast shadows like the moon. It left no streak, but it had a short tail, and in colour it seemed yellow or orange. Three minutes after its disappearance [the time taken by sound to travel about 36 miles] a rumbling sound like distant thunder was heard proceeding from its direction. The motion of the nucleus in the last part of its flight seemed to be slightly zigzag.

The distance of the observed end point of the meteor's course from Leicester is 31 miles; and a point 10 or 12 miles before the end point, along the meteor's course, is 36 miles from Leicester, so that sounds produced by the explosion, and by resistance to the motion of the fireball in the last ten or twenty miles of its course, appear to have been those heard at Leicester, like the rumbling sound of distant thunder. At Birmingham no sound of the explosion was perceived, although the distance of the end point of the meteor's flight was only twenty miles from the observer there; but the circumstance that the track was directed nearly towards him, may have been less favourable than its flank presentation towards Leicester for conveying to that distance the rumbling sound of its passage through the air; and as it does not seem to have been a loud sound at Leicester, it may also be owing to its slightness that the report of a terminal explosion, which may really have taken place at the end of the meteor's course, was not noticed by the Birmingham observer.

1878, May 12, 8^h 53^m p.m.—A detonating fireball (?); Yorkshire to near Edinburgh.—This fine (and perhaps detonating?) fireball made its closest approach to the earth in the neighbourhood of Edinburgh; and accounts of its appearance there, and at places not far from Edinburgh, published in the 'Scotsman' of May 15 and 16, and in 'Nature,' of May 23, by observers of its course, give very graphic descriptions of the brilliant spectacle which it presented. Accounts at Wigton, in the south-west part of Scotland, at Derby, in London, and at Calne, in Wiltshire, were furnished also in the 'Scotsman' of May 20, the 'Derbyshire Advertiser and Journal' of May 17, 'Nature,' and the 'Times' of May 16; further observations of its path of special accuracy being also supplied from several towns in Yorkshire, in an article by Mr. J. E. Clark on the real path of the meteor, in the 'Natural History Journal of Societies in Friends' Schools' of July, 1878, in which he discussed all the observations of it in England of which he had received information. One of the best of these was by Mr. W. T. Jackson, at York, who, with a party of friends sitting in a gaslit room, saw the meteor descending, in a north-west direction, through window panes, with a direction of fall towards the earth, which was absolutely vertical. There was still much light in the sky, and stars were only dimly visible, but Capella was observed near the meteor's course, about 9° or 10° on its left, as was accurately ascertained by measurement. Rough sketches of the stars, showing the meteor's track among them, were also furnished to Mr. Clark by observers

of its whole course at Scarborough and Whitby. That drawn at Scarborough by Mr. Rowntree assigns one point of the meteor's passage near β Aurigæ, at about $97° + 41°$, with tolerable clearness, and with some degree of approximation; the course shown at Whitby (not very far from Scarborough) also confirming the same position of its apparent path at the place where the fireball in its downward course reached this point of its descent. Combining the description with that of a corresponding point noted at York of the meteor's downward path, the real height and locality of the fireball, when its apparent altitude at York was a little above that of Capella, is found to have been just 50 miles over the little chain of the Northumbrian lakes lying in the north part of the valley of the Tyne between Haydon Bridge and Haltwhistle. A projection on the map of the meteor's onward line of flight from this point (by a straight line drawn through it from York towards the point of the meteor's vertical descent, horizonwards, 36° west from north) passed (northwestwards by north) through Hawick, and nearly over Selkirk, Galashiels, and Peebles to Linlithgow, about 15 miles west of Edinburgh, on the Firth of Forth. In its last part the track follows the direction of the valley from Galashiels to Edinburgh, leaving Galashiels itself six or seven miles, and the rest of the valley as far as Edinburgh ten or twelve miles on its right. An observer on the Edinburgh road one mile north of Galashiels "saw a very large and brilliant meteor pass along the valley to the north-north-west. The head was large and round, like a ball of electricity, and the tail long and tapered, as brilliant as the head. It was in view for five or six seconds, and seemed at the end to melt into nothing. Two minutes after its disappearance [a time taken by sound to travel twenty-five miles], I and others heard one loud deep peal, as of thunder, and a quarter of an hour later sheet lightning began to flash, and continued to do so at intervals for a considerable length of time."—(J.S.: the 'Scotsman,' May 16th, 1878.)

The presumptive course of the meteor arrived at by Mr. Clark, from a projection of all the English observations, was from between 75 and 80 miles above Northallerton, in Yorkshire, to about 22 miles over a point five miles west of Hawick, a flight of 108 miles in about nine seconds, descending at an angle of about 38° to the horizon. But in this projection the only Scottish observation used (by Mr. D. R. Stewart, in Edinburgh, 'Nature,' May 23rd, 1878) was employed for the commencement only, the description of the end point (see a letter by Mr. Clark in 'Nature,' of June 6th) being a little ambiguous, while it appears to indicate that the real end point of the meteor was actually far north of Hawick, and perhaps even, according to Mr. Stewart's description, a little north of Edinburgh. A letter received by Mr. Clark from Mr. D. R. Stewart, soon afterwards, confirms the latter supposition, and describes again the apparent place in the sky of the meteor's point of disappearance near Edinburgh, almost exactly as it was before noted in 'Nature,' but more clearly and distinctly. From his point of view at Kirknewton, Edinburgh, the meteor began at an altitude of about 50° above the S.S.E. horizon, some 30° east of the moon [then 5° west of the meridian, alt. 31°, at Edinburgh], and passing somewhat west of the zenith reached a position, when it burst and disappeared, about 30° or 40° N.W. by N. from the zenith point of his position. Another observer in Edinburgh, who saw the meteor's flight from a window facing south, was so impressed with its apparent descent at last towards the direction of Fettes

College and Corstorphine hill (a little north of west from Edinburgh) that he ran to an opposite window to see it fall there, but it did not reappear. At Bathgate, 18 miles west of Edinburgh, "it came in sight about 20° above the horizon, S.S.E., and went up N.N.W., nearly right overhead."—('Observer,' the 'Scotsman,' May 16th.) The above projection of the meteor's path, derived from the York account, passes midway between Edinburgh and Bathgate; and as the note of its course at Bathgate contains no statement if the meteor's point of disappearance, when nearly overhead, was on the east or west side of the zenith point, the end point cannot be assigned more exactly from these descriptions than at a height of about 20 miles above the Firth of Forth near Linlithgow, to which point, lying W.N.W. from Edinburgh and N.N.E. from Bathgate, the track would pass about 20° west and east respectively of the zenith points of those two places.

To determine the inclination of the meteor's descending path to the earth's surface, no sufficiently exact observations were recorded; but it may nevertheless be inferred, with considerable probability, from the combined descriptions. When first seen in the S.S.E., at Edinburgh, its altitude was not much greater than that of the moon (31°), and it began at an altitude of 20° only, according to the account at Bathgate. Recollecting that apparent altitudes are always much over-estimated by the unassisted eye, and that the initial point as seen at Edinburgh must have been *above* the meteor's radiant point at least some few degrees, it seems scarcely possible to assign a much higher altitude than about 20° for the radiant point, or a much steeper slope of the meteor's path than this towards the earth's surface. This is also the slope of a line of flight from 50 miles above the Tyne valley to 20 miles above Linlithgow, where two points of the real path were found to lie approximately; and it passes 36 miles from Galashiels, a distance which requires 3 minutes (instead of two minutes, which is said to have elapsed) for sound to traverse it. If a lower height of about 15 miles near Linlithgow is adopted for the end point (which seems very probable), the slope of the resulting real path is then 22°; in the first case the height which the real path prolonged backwards had at Northallerton was 72 miles, and in the last case 78 miles, and the distance of the meteor's track from Galashiels is 34 miles in the latter case, instead of 36, as in the former one. The heights of 72 and 78 miles over Northallerton agree very well with the height of 75 or 80 miles over the same place at which Mr. Clark estimated, from a collective projection of all the English observations, that the meteor began its flight; but by the removal of the end point from a place near Hawick to one at about the same vertical height near Edinburgh, the slope of path is diminished from 38°, as deduced from the English observations, to 20° or 22° when the views of the fireball obtained about Edinburgh and in some other parts of Scotland are included. The observers' positions at Stonykirk (near Stranraer) in Wigtonshire, and at Preston, were, of all the places where it was observed, the most favourable, by the flank views which its descending path there presented for determining the radiant-point; but the apparent slope at those places was not noted, and at Stonykirk only one datum of the meteor's apparent position was recorded, that the splendid sight of its passage in the heavens was in the direction of New Galloway, which, when prolonged far enough from Stonykirk, coincides with the position of the meteor over Galashiels.

With a downward inclination of path from 22° above the horizon, 36° E. from S., the radiant point of this detonating fireball (as there is good ground to suppose it to have been, from the Galashiels account) was in R.A. 214°, S. decl. 7°. In April and May, 1877, Mr. Denning and Mr. Corder noted a rich and well-defined shower of bright meteors (some conspicuous ones of which were seen on May 15th) from an apparently new radiant point, the various indications of which, traced also by Mr. Denning's reductions from other sources, are presented in the following list by Mr. Denning, who regards them as all pertaining to a single shower:—

		α	δ	
April 1–12, 1872, 7 $\downarrow$s in the Italian Catalogue	pos of rad.	204°	− 8°	Average position 207°−8°. Radiant point of the fireball of May 12th, 1878, 214°−7°.
May 3–15, 1872, 9 $\downarrow$s in the Italian Catalogue	„	209°	− 8°	
April–May, 1872–77, 23 $\downarrow$s from various Catalogues	„	203°	− 8°	
April–May, 1877; observed by H. Corder	„	208°	− 6°	
May, 1877, 3 $\downarrow$s „ W. F. Denning	„	210°	−10°	

As far as exact conclusions drawn from rough and imperfectly recorded, but at the same time fairly corroborative, observations, like those of the present fireball, can be depended upon, it seems a not improbable assumption that the great fireball here described was a large and brilliant member of this recently-detected, and apparently very conspicuous and abundant meteor shower; but the agreement is yet not so exact, nor quite so directly and positively established by the observations, as to make the possible connection of a *detonating* fireball with a shower of ordinary shooting-stars, which it seems to indicate, a conclusion which it will be unnecessary to confirm and verify hereafter (in future reappearances of this meteor-stream, and of fireballs apparently conformable to it) by further observations. It seems very probable that the meteor-shower here newly recognised may be identical with one observed by Prof. Forshey, in the United States, on April 18th, 1841, the chief features of whose somewhat remarkable display, as described by E. C. Herrick in the 'American Journal of Science,' vol. xlii. p. 395 (April–October, 1842) were as follows:—The frequency of the meteors on the night of April 18th, 1841, first struck Prof. Forshey at about 8 o'clock p.m. During a watch of about $2\frac{1}{4}$ hours between $8^h\ 30^m$ and $11^h\ 30^m$ p.m. he recorded 60 meteors, the tracks of all but five of which proceeded from a radiant point between α and θ Virginis, a little nearer to the former star, at 198° − 8°, with a deviation of the backward prolongations of their courses from this point, which seldom amounted to so much as 10°. The radiant point is almost exactly on the ecliptic in longitude 196°. The meteors seen in these unusual numbers differed entirely in appearance from the August Perseïds, being chiefly without trains, and of a reddish colour. Few of them were of the first magnitude, the majority being of the brightness of stars of the third and inferior magnitudes; their velocities were remarkably equal and gentle, their paths short, and their light gradually increasing and then waning in its brightness. As the radiant point of the shower is just opposite to the sun's place, and transverse to the direction of the earth's motion, at the date of its appearance, it would be of special interest to ascertain, if possible by observations, the exact real velocity of the meteors of this shower, and thus to deter-

mine with an amount of probable error, which would only be very small and insignificant, the real eccentricity of its orbit round the sun.

The whole length of the meteor's path from over Northallerton to the Firth of Forth was 155 miles, but only the last 100 miles of this track (from about over Alston at the junction of the counties of Durham, Northumberland, and Westmoreland) was visible at York. The duration of this part of its flight was six seconds, measured independently by several observers' recollections of it; and its light was first noticed about three seconds before the meteor itself was seen, which agrees with the first third part of the length of its path in which the meteor was unobserved. Most of the observers give five or six seconds as the time of flight in the part of the meteor's path to which their view of it extended: and a duration of nine or ten seconds for the whole path of 155 miles is thus probably not far from the real time of passage of the meteor along this length of course. The velocity of the fireball's motion on this computation was about $16\frac{1}{2}$ miles per second, while the velocity of a body from the same radiant point, moving in a parabolic orbit, is 15 miles per second. This result conducts us, therefore, to a fairly probable conclusion that the meteor's real orbit was not far from being one of a parabolic form.

The head of the meteor was round, ending in a tail of moderate length, consisting of sparks, which at a distance seemed red, but among which some bright fragments of other colours were also visible to observers nearest to its track: one of whom described its nucleus as double, and another as ending behind in a long tail as brilliant as itself. Just before its disappearance a fragment, or body of red sparks of considerable size, seems to have detached itself from the head, and it is not impossible that the explosion heard at Galashiels may have been caused by this disruption, of which no sounds are nevertheless recorded to have reached Edinburgh or other places closer to the point of the meteor's final disappearance. Though flashes of distant or "sheet lightning" were seen at Galashiels, and continued for some time (unaccompanied it would seem by thunder), about a quarter of an hour after the occurrence of the fireball, yet the sky seems to have been pretty clear at Galashiels at the time of the meteor's passage, and the later occurrence of flashes of distant lightning there appears to offer no sufficient explanation of the "one deep peal of thunder" which the observer of its transit there relates that he heard two minutes after the fireball's disappearance. If the illuminating power of the nucleus was very great, the strength of the light which it cast is not expressly noticed by any of the writers who described it, but it may be presumed that near Edinburgh, where its apparent diameter was about one-sixth of that of the moon, its light must have been sufficient to cast observers' shadows on the ground. At York its apparent brilliancy was described as almost equal to that of the planet Venus. The nucleus emitted no sparks, but split into two at the end, one part about $\frac{1}{4}°$ in advance of the other when they both disappeared, apparently, behind a thin cloud that stretched above some trees near the N.W. horizon.

1878, June 7th, 8^h 30^m, and 9^h 53^m p.m. large fireballs, Devonshire, and the south of England.—Two fireballs, of which the second was much the largest, passed across the south-west part of England, both remarkable for their long courses and slow flight, on the evening of this date. Mr. Lighton's observation of the first (see the catalogue for the full descriptions of the courses and appearances) gives the point of the horizon

about 45° or 50° E. of S. (R. A. about 250° or 255°) from which it was directed. Its very slow and long protracted flight, and the form and colour of its nucleus, resembled those of the later meteor, and its observed course, presumably horizontal, appears pretty certainly to have been directed from the same radiant-point. It did not emit sparks nor oscillate in its progress as the later and larger meteor seemed to do. Captain Cunninghame, at Bathwick, also saw both meteors, the second larger than the first, but resembling it otherwise in the characters of its appearance. Mr. G. H. Holmes describes the first as singularly splendid even in the nearly full daylight which prevailed. It was pale green, like a globe of liquid fire sailing through the sky (Bristol newspaper accounts, communicated by Mr. Denning).

The next fireball, at 9^h 53^m p.m. was very widely noted in the south of England. Mr. Denning's view of it at Bristol, however, supplies the only precise data upon which calculations of its real path can be founded. Observers at four places in Kent, and in the neighbourhood of London, assign various heights at which it passed almost horizontally below, while at Bristol it passed 6° above, the moon. At Silverton, near Exeter, it shot towards Ursa Major (a little west of the zenith), and disappeared a little beyond that constellation, and in Jersey it was seen to commence about 30° from the zenith, in the north, and fall towards the horizon. A common plane perspective projection of all these apparent paths on a single map of the sky at the time of the meteor's appearance shows that its path was very little inclined to the earth's surface, and suffices to fix its real place and altitude with fairly satisfactory exactness.

The fireball began its course at a height of about 65 miles over a point in the English Channel, near the Channel Islands, about 20 miles W.N.W. from Guernsey, passed nearly over Start Point and the main land to Bideford Bay, descending gradually to a height of about 37 miles over a point in the Bristol Channel, 12 or 15 miles E.N.E. of Lundy Island, where it disappeared. The length of this course is about 160 miles, descending with a slope or inclination to the earth's surface of about 9° or 10° from the direction of about 23° E. of S. The radiant point was at R A. 247° decl. $-25°$, within three or four degrees. From a description of the duration of the flight at Hawkhurst, where it was well observed, it may be reckoned not to have exceeded eight or nine seconds, although durations varying from three or four to twenty or thirty seconds are elsewhere assigned to the time occupied in its long course, with its slow majestic speed. The real velocity of its motion given by this estimation is about 19 miles per second; while that of a meteoric body revolving round the sun in a parabolic orbit, and having the same radiant point, would be 20 miles per second. The meteor did not burst, but threw off some sparks, and had a short waving tail, with a slightly oscillating motion, or flickering changes of brightness as it sailed along. It disappeared suddenly, without leaving any streak, or producing an audible explosion. Its radiant point closely resembles in position that of the great detonating or aërolitic meteor of June 17th, 1873 (see these Reports, Vol. for 1878, p. 145), seen in Austria and Bohemia, which was found, by Dr. Galle and Prof. von Niessl, to be at R.A. 248°, decl. $-20°$; and it is, like that of several large meteors which have occasionally been noted in June and July, in the neighbourhood of the ecliptic, and of the bright star Antares (α Scorpii, at 245°·5—26°·0).

The adopted radiant point of this fireball, at 247° $-$ 25°, is on the back-

ward prolongation of the apparent track observed by Mr. Denning, about nine or ten degrees above the horizon, due S.S.E. The linear prolongation of the Bristol track is directed from due S.E. to due N.W. with a slope of 28°. The apparent paths in Kent, and near London, noted as passing "horizontally" underneath the moon (then due W.S.W., alt. 22°) at variously recorded altitudes from 12° to 20°, since they present a point of *convergence* above the horizon with the Bristol track, are thus far inadmissible. But, assuming, as is probable, that the apparent path observed by Mr. Denning is exceedingly trustworthy, the least possible correction which the Kentish tracks require is a slight inclination earthwards, near the moon, sufficient to depress their point of convergence with the Bristol path to the horizon, and to the same apparent earth-point, due N.W. for all those apparent paths, as that of the meteor's course at Bristol. With this slight emendation of those which were observed in the south-eastern part of England, the real course of the fireball would be parallel to the earth's surface, 40 or 50 miles above it, from S.E. to N.W. But the observation at Prees, about 15 miles north of Shrewsbury, where the meteor must have travelled at an altitude of about 15° from S. to S.W., that there it "appeared first in the south, moving horizontally westwards," is less easy to reconcile than the Kentish observations with a truly horizontal flight of the fireball from a radiant point at the S.E. to a point of convergence at the N.W. point of the horizon, and shows very clearly that the real position of the radiant point on the apparent line of flight observed at Bristol was not at or close to its intersection prolonged backwards with the horizon, due S.E., but at some point upon it at an appreciable altitude *above* the horizon, more nearly south. The above adopted real path has at its commencement, as seen from Prees, near Shrewsbury, a slight upward slope of barely 10° at starting in the south, beginning there at an altitude of 14°, and just reaching its greatest altitude of 17°, 35° westwards from this point in the S.W. by S. At Hawkhurst, Greenwich, and other neighbouring places in the S.E. of England, it began at alt. 17°, also the highest possible altitude of its course there, and passed 7° below the moon (at an altitude of 15° W.S.W.), descending there with a slope of about 7° from horizontal towards an earth-point 40° N. from W. and disappearing at an altitude of 8° or 9°, just one point N. of west. While this course almost exactly represents the observed altitudes in Kent, with the exception of that of commencement (which measured by memory in the open sky was uncertain) at Hawkhurst, it begins, just as the Shrewsbury apparent path ends, horizontally, and at the points where the apparent course was described as "horizontal" in Kent and near Shrewsbury the real direction was descending with a slope of 7° at the first, and ascending with a slope of 10° from horizontal at the last of those points of view. No fairer distribution of the scarcely sensible errors of description which present themselves in the two accounts can probably be made, and the very good adjustment to each other, of which they actually admit, shows that the radiant point above adopted must be very nearly the true one, and that the track of the fireball as above derived from those descriptions, represents, in all probability, very closely the height, direction and position of the fireball's real flight above the earth.

Even in Kent amidst the rays of the moon and of twilight, the meteor's light was stronger than, and cast a distinct shadow like that of the moon. The longer diameter of its nucleus, at Twickenham, near London, appeared

about one-third of the moon's diameter; at Silverton, near Exeter, its head had an apparent width of about one-half, and at Versailles, and in Aisne, France, where the fireball was also seen, its apparent width was about one-sixth of the diameter of the full moon.

1878, July 29th, 9^h 25^m (or ? 9^h 31^m) p.m.—Large fireball, near Manchester and Lancaster. Good observations of this meteor's course were fortunately obtained by Mr. R. P. Greg at Styall, 11 or 12 miles south of Manchester, and by Mr. Thomas Kay at Middleton, about 5 miles nearly due north from Manchester. At the latter place the momentary track of fire which the meteor left on its whole course enabled Mr. Kay to fix its line of flight very accurately from an initial point in Lyra to a terminal one in Canes Venatici, just grazing the star η Ursæ Majoris in its path. At Styall, 16 or 17 miles south from Middleton, the meteor's course was directed from the head of Draco, and Lyra, and its terminal part passed through the middle of the square (α, β, γ, δ) of Ursa Major, and ended immediately beyond it. These two observations fix the end-point of the meteor's course very exactly, at about 20 miles high above a point near the mouth of the river Ribble, between Preston and Blackpool. Its apparent descent to this point, northwestwards, was almost exactly vertical to both of the Manchester observers. The remaining descriptions of its apparent course concur to show that the real direction of its descent was, in fact, almost truly vertical, but at the same with an inclination, from the south-east, of somewhere about 20° from perpendicular. Thus at Whitehaven and at Lancaster, both nearly north from its end-point, its nearly vertical descent in the S.S.E. and S.S.W. was from the north-east, and from about 15° east of the zenith, respectively, at those places. At Bristol, 150 miles south from its end-point, it fell in the haze of the north horizon almost vertically from the region of Cassiopeia, which is (if the meteor really shot from the direction of Cassiopeia) from about 35° east of the zenith. The point of commencement of the Middleton track is itself almost exactly in the zenith of that place, and with the meteor's long apparent course there of over 50°, a less distance than 10° or 20° at starting, from its radiant point, can scarcely be regarded as admissible. A radiant point on the apparent path at Middleton retraced 20° south-eastwards from the zenith, is at 300°, + 35°, (R.A. and Decl.), near η Cygni, and to which of the numerously recorded radiant points in Cygnus at the end of July this brilliant fireball's rapidly descending path was really to be ascribed it is scarcely possible now to determine more exactly from the rather scanty observations. The backward prolongation of the observed path at Middleton passes, in fact, on each side of this point, nearly parallel to the stars δ, ϵ Cygni (in the swan's right and left wings); and it appears uncertain nearer to which of these two wing-stars of the constellation the fireball's apparent radiant point may not impossibly be supposed to have been situated a little more correctly than near the middle point between them. The nearest point of the line to δ Cygni is at 290°+42°; and a little nearer to the zenith, it passes near π Lyræ, at 285°+45°; while among a large number of shooting-stars seen by Mr. Denning on the last two or three nights of July, 1878, a radiant of bright slow moving meteors was observed at 284°+44°. But these two places are only 10° and 6°, respectively, S.S.E. and S. by E. from the zenith, and this agrees imperfectly with some of the descriptions of the meteor's obliquely descending course. Nevertheless, it may very fairly be conjectured that this exceedingly brilliant

fireball was in reality one of a very closely adjacent group or system of ordinary shooting-stars to that observed by Mr. Denning.

With this observed radiant point the beginning of the meteor's course at Middleton was 82 miles above a point about 8 miles west from Manchester; its length, to the point of disappearance is 70 miles, and its duration as estimated by the length of time occupied by the flashes and illumination until the meteor disappeared, was a second and a half, or between two and three seconds, as noted independently by Mr. Greg and Mr. Kay. Some luminous portion of its path was, however, probably traversed by the meteor before the first flash which drew their attention to its descent; and for the whole length of the course upon which the light-track was traceable which marked its path, a time of flight of about three seconds may fairly be assumed from these descriptions to be rather a somewhat insufficient, than in any degree an over-estimated or exaggerated duration. The real velocity of the fireball which it gives, is 25 miles per second; while that of a meteoric body moving with the same radiant point in a cometary or parabolic orbit, would be 21 miles per second—a little less; implying apparently a small under-estimation of the whole time of flight by about half a second.

A nearer approach to the theoretical meteor speed could scarcely be expected when the unforeseen and momentary character of the observations is considered, from which by the united evidence of all the particulars of the descriptions the meteor-speed is obliged to be finally determined.*

The meteor was a very large and vivid one, its light making the smallest objects visible, at Manchester, and its luminous disc having an apparent diameter there of quite one-half that of the moon. It presented two flashes, one previous expansion occurring, before that of its last outburst, which Mr. Greg regarded as much more brilliant, and as having shone from the meteor somewhat before it can have reached the middle point of the above vivid portion of its flight, at a height accordingly of not

* From Mr. T. Ellison at Colwyn Bay, and Mr. J. E. Walker at Loweswater, Cockermouth, Mr. Greg and Mr. Clark (*vide* 'Natural History Journal' for September, 1878) received descriptions of the meteor which show that its end point may have been as far west as 5 or 10 miles off the coast, between Blackpool and Fleetwood, at a height of some 30 miles over the mouth of Morecambe Bay, instead of 20 miles over the Ribble mouth near Preston. The meteor then ended its course at an apparent altitude of 30° or 32°, as seen at both Conway and Loweswater, a little east of their north and south meridians. The descriptions at those places answer very well to this position, although the recorded altitude (55° or 60°) at Loweswater perhaps refers to the first and brightest portion of the flight, or may have been overrated, as is usual in eye-estimations.—While the direction at Conway is drawn as descending a little obliquely from east towards north, which agrees with the general impression furnished by the other observations, the statement that its course at Loweswater was descending from S. towards S.E., with a slope of 40° from horizontal, or from considerably *west* of the zenith there, cannot be reconciled with the remaining descriptions, nor even, apparently, with one of the recorded statements of its apparent motion at Whitehaven, that "the position of the meteor as seen from that town was about due south, and its course about [? from] north-east." Mr. Walker only saw the end of the meteor's flight askance: but its light-streak of 10° remaining visible for a minute would not allow the discrepancy of his description to be thus explained. From such conflicting data it can only be provisionally concluded that the meteor's radiant-point was near the zenith, and that along the line given by the observers' notes of it near Manchester by the stars (Mr. Greg's and Mr. Kay's), it was probably less rather than more than 20° eastward from the zenith.

less than 50 or 60 miles above the earth's surface, and at a distance from Manchester of not less than 60 miles. The end point of its flight was about 30 miles distant from Manchester. An observer there ('V. R.' 'Manchester Courier,' August 5th, 1878), describes its light during this last most effulgent part of its course as "equal to the electric light at Belle Vue when you stand 30 or 40 yards from it, on the far side of the platform; quite as much I should say." At 45 miles instead of 35 yards the fireball must have shone with the brilliancy of $(2{,}263^2)$ or 5,121,169, such electric lights! We may, perhaps, assume that for three seconds it illuminated Manchester with a glare equivalent to the mechanical strength of something less than half this number of horse-powers, expending therefore $\frac{33000}{20} \times \frac{(2263^2)}{2}$ foot-pounds, or 4,224,964,425 foot-pounds of energy in its brief career! Moving with a velocity of 25 miles per second, a single pound-weight of matter possesses 270·555 millions of foot-pounds of energy of motion, so that to account for the fireball's expenditure of 4,225 millions of foot-pounds of energy, it suffices to suppose that $4{,}225 \div 270\frac{5}{9}$, or 15·616 lbs. weight of matter composing its substance was brought suddenly to rest by the enormous force of resistance of its collision with the air! The average pressure of this resistance in a flight of 70 miles must be 4,225 millions $\div (70 \times 5280)$, or 11,431lbs., and this pressure of nearly five tons against its front surface would instantly comminute and disperse any liquid or pulverulent substance, making it obvious that the masses of shooting-stars, and of very luminous fireballs like the present one, are really hard and compact stone, exactly as we find those of aërolites to be.

The intensity of the fireball's incandescence or ignition seems to have been rather remarkable, as the light which it cast was bluish, and was everywhere compared (about Manchester, at Conway, in Wales, &c.) to sheet lightning, to the electric and limelights, and to daylight. It is, therefore, not at all improbable that its powerful glare may have been generated from a much less expenditure of mechanical energy than that here represented, and that not only the mechanical action but also the weight of meteoric substance, and the pressure on its surface here supposed may be somewhat overrated. The nucleus nevertheless underwent progressive disintegration all along its track, leaving a long string or stream of countless red sparks, stars, or beads of fire in its wake, which remained visible for a short time after the meteor's disappearance. It did not burst and fly to pieces at last, but collapsed and disappeared rather suddenly, and at places near which it descended to no great distance from the earth no sound of any audible report following its extremely brilliant flashes seems to have been perceived.

III. Meteoric Showers.

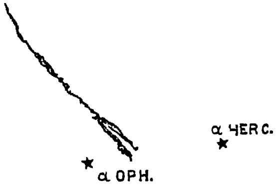
Somewhat plentiful displays of meteor showers, both occasional and on the well-known annual dates, have been recorded during the past year, a list of which is here appended where the date and the frequency of the meteors and the position and accuracy of their radiant point were sufficiently remarkable to make the observations of special interest, or of any particularly new and significant importance. With the exception of a few contemporaneous and foreign observations, they are almost all

extracted from an original list of 162 meteor showers seen in the year 1877; which was published in March, 1878, by Mr. Denning, in the 'Monthly Notices' of the Royal Astronomical Society (vol. xxxviii., p. 305). The present list includes also some notes of the same, and of later showers in the year 1878, which Mr. Denning obligingly communicated to the committee. Of the August Perseïds, in 1877, some other descriptions having been received, a short account of the additional observations since collected is here presented to complete the brief notice of that shower which was given in last year's Report.

Meteor shower of August, 1877.—Observations at York, by Mr. J. E. Clark. The sky was often cloudy on the 9th, and watch was only kept for twenty minutes, in which ten meteors were seen, six of which were Perseïds. On the night of the 10th, the sky, while watched, was little more than half clear. A lull of fifteen minutes occurred, commencing at 11 o'clock, in which there were seen only two Perseïds and three unconformable meteors. In the hour between $11^h\ 30^m$ and $12^h\ 30^m$, thirty Perseïds and two unconformable meteors were seen, and twenty of their tracks were mapped. The principal radiant was not very well defined, a good many meteors coming from the Andromeda side of Perseus. Several of the streaks left were very fine and long enduring.

Observations at Writtle, Chelmsford, by Mr. H. Corder. The sky was watched for four hours on the night of the 10th, and was partly clear. 104 Perseïds and eighteen unconformable meteors were seen, the Perseids appearing at the rate of about twenty-six (equal to forty or fifty in a clear sky), and unconformable meteors at the rate of about four (equal to seven or eight in a clear sky), per hour. Forty-eight of the Perseids seen left streaks, three bright flashing meteors leaving fine reddish trains visible for about twenty seconds. The radiant point of the shower was rather diffuse, with a mean place at $47° + 62°$.

On the night of the 11th the sky was watched, partially clear, for three hours, seventy-six Perseïds and eleven other meteors being noted. Thirty-eight of the Perseïds left streaks, their average horary number was twenty-five, and that of the unconformable shooting-stars four per hour; but during the clearest half hour the average horary number of the Perseïds reached forty-eight per hour. None were so brilliant as the flashes seen on the previous night; but some were quite equal to Sirius, and one of the largest of these left a forked streak divided into two branches thus,



in the last few degrees of its course, which ended at a point about one-third way from α Ophiuchi to α Herculis. The radiant, better defined than on the previous night, was at $58° + 56°$. From the two determinations of its place, Mr. Corder suspected a gradual progression of the radiant-point on the two successive nights.

The Perseïds in this shower were swift. Thirty of them were as

A LIST OF REMARKABLE METEOR SHOWERS

Date, and (Horary or) Total Numbers				Position of Radiant Point		
Maximum Date	No. of ↓s	Total Duration	No. of ↓s	α	δ	By the Stars
1877, Jan. 4, 7 ...	Two, large	Jan. 4–20	7	57°	−12°	Near γ Eridani..... ...
Jan. 17	Many	Jan. 4–20	20	295	+53	Near ι ψ Cygni ....
Feb. 15–20	10	....	...	236	+11	Near α Serpentis ......
Feb. 20	6	....	...	263	+36	Near ρ Herculis.........
Feb. 20	8	....	...	181	+34	Canes Venatici ....
March 14 ...	6	....	...	263	+48	ι Herculis ....
April 16–19	5	....	...	228	− 2	Near δ Libræ............
April 16–19	7	....	...	269	+37	Near θ Herculis.........
April 19 ...	13	....	...	275	+35	Near κ Lyræ ....
May	3	April—May	?	210 203	−10 − 8	Near κ Virginis......... Near α Virginis.
July 7–11 ...	...	July 6–17 .... and Aug. 3–16	21 16	4 10	+35 +38	π Andromedæ .... ν Andromedæ.
July 12–17	...	July 6–17 .... and Aug. 3–16	11 9	6 8	+53 +53	α Cassiopeiæ ....
July 20	...	July 6–20	13	317	−11	Near μ Aquarii ....
....	...	July 6–17 .... and Aug. 3–16	8 7	290 292	+43 +48	Near δ Cygni... ....
Aug. 3–16...	10	....	...	342	−12	Near θ Aquarii ....
Aug. 3–16...	18	(and July 6–17) ...	6	335	+45	Lacerta ....
Aug. 4	...	Aug. 3–16 .... (and Sept. 4–16).	7	22	+46	γ Andromedæ ....

OBSERVED DURING THE YEARS 1877-78.

Appearance of the Meteors	Observer, or Reference	Comparisons with earlier observations, and with Comet Showers; and Remarks
Fine slow meteors; two bolides, Jan. 4 and 7.	D. (77) 2, ('Nature,' xv. 346).	Parabolic velocity 12, bolide of Jan. 7 at least 19 m. per sec. (?). (These Reports, 1877, pp. 135, 142.)
Strong shower of bright slow ↓s.	D. (77) 1, ('English Mechanic,' March 2, 1877).	Meteors tailed, but left no streaks. Only seen between Jan. 4 and 20; a few of these tracks are from other observers' lists. Radiant new for January.
....	D. (77) 13	Radiant exact; a strong morning shower.
Rapid bright meteors	D. (77) 14	Radiant exact; a rich morning shower. (Corder, Jan. 27, 263° + 36°.)
Ditto	D. (77) 15	Ditto; ditto.
....	D. (77) 22	Ditto; confirms SZ. 46, April 1, 261° + 47°.
....	D. (77) 39	Ditto; a rich shower. GH. 53, 227° − 5°, March 20—May 29.
....	D. (77) 40	*Lyrids* at 274° + 37° in 1873 and 1874. = Comet I, 1861. Only five Lyrids seen in five hours on the morning of April 20th.
....	H. Corder (Writtle, Chelmsford).	Lyrids not numerous; thirteen in about two hours, with this radiant on the morning of April 20th.
....	D. (77) 46	A rich and probably new shower. Corder, April—May, 208° − 6°. [(?) = Forshey, April 18, 1841, 198° − 7°; a fine shower; and bolide May 12, 1878, 214° − 7°.]
....	D. (77) 49	Andromedes I; G 103; very active; diffuse; recurs Aug. 3-16; distinct from α Andromedes of the same dates (Denza, Aug. 8-13, 2° + 29°); = ☄ 1780 II., Aug. 14, 3° + 38° (?).
Swift white meteors, with streaks.	D. (77) 53	Cassiopeiads; a fine shower, radiant exact; (SZ. 130, 138). Distinct from D. 78, Aug. 3-16, fifteen ↓s, at 18° + 63°. Continues in Sept. and Oct.
....	D. (77) 57	Strong max. July 20; T. 37, 44, July 21, 22, 313° − 6°.
....	D. (77) 55	A well-marked radiant. GH. Aug. 10, 1871, 293° + 42°. (A strong radiant on same dates at 315° + 50°, near α Cygni; ? = Coggia's ☄, 1874, III.)
....	D. (77) 59	A distinct shower in Aquarius; (at 336° − 7°, five ↓s, July 6-17 ?).
Very swift meteors	D. (77) 62	Lacertids; a very active August shower. The real centre is at 334° + 48°.
....	D. (77) 75	A new shower, with max. on Aug. 4 Another active shower of short swift meteors, Aug. 3-16, with exact radiant at 30° + 36° (near β Trianguli), D. 91, recurs Oct. 2-18 (max. Oct. 8), at 31° + 39°, ten ↓s, D. 124.

A LIST OF REMARKABLE METEOR SHOWERS

Date and (Horary or) Total Numbers				Position of Radiant-point		
Maximum Date	No. of ↓s	Total Duration	No. of ↓s	α	δ	By the Stars
1877. Aug. 10–12	10	....	...	70	+65	Camelopardus ....
Aug. 12......	...	Aug. 12–16...........	11	31	+18	θ Arietis ....
Aug. 12–16	...	Aug. 3–16	11	61	+48	μ Persei ....
Sept. 4–16...	7	(and Sept. ?) .... (and July 6–17,...... Aug. 3–16)...........	5 5 6	47	+45	Near ε Persei...........
Sept. 4–16...	10	(and Oct. 2–18)......	8	220	+78	Near β Ursæ Minoris
Sept. 7–16...	...	Sept. 4–16	15	61	+36	Near ξ Persei..........
Sept. 5 and Oct. 5–8 ...	... ...	Sept. 4–16 .... Oct. 2–19	8 18	85 84	+53 +55	Near δ Aurigæ ....
Oct. 2	7	....	...	225	+52	Head of Bootes...... ..
Oct. 3–4 ...	...	Oct. 2–20	17	310	+77	Near κ Cephei ....
Oct. 3–4 ...	13	Oct. 2–18	22	133	+79	P Camelopardi ....
Oct. 8	...	Oct. 2–19 .... and Oct. 28–Nov. 13	22 11	103 107	+12 +11	Head of Monoceros ...
Oct. 2–19 ...	15	and Oct. 28–Nov. 13	21	105	+50	g Lyncis..... ....
Oct. 15 and Nov. 12......	... ...	Oct. 15–19 .... Oct. 28–Nov. 13......	18 12	133 127	+21 +17	Near δ Cancri .... " ....
Oct. 15, 16	...	Oct. 2–19	11	130	+47	ι Ursæ Majoris ....
Oct. 16, 17	(14)	About Oct. 15–20 ...	53	89 95	+18 +17	Near ν, ξ Orionis ......

OBSERVED DURING THE YEARS 1877–78—*continued.*

Appearance of the Meteors	Observer or Reference	Comparison with earlier observations, and with Comet Showers; and Remarks
....	D. (77) 77	Camelopardids. A new well-marked August shower.
Meteors with streaks	D. (77) 82	A strong max. on Aug. 12; a new A. M. shower. (The same radiant 30° + 16°, eleven ↓s, seen Oct. 28—Nov. 13; D. 138).
....	D. (77) 83	A well-marked shower and max.; radiant exact.
....	D. (77) 63	Apparently a long-continued shower, quite distinct from the η Perseids of Aug. 10.
Swift meteors	D. (77) 94	A well-defined active shower, less marked in October than in September.
Rapid meteors, with streaks	D. (77) 96	A rich shower; radiant exact. Two radiants also of rapid ↓s with streaks (D. 123, 126), with max. on Oct. 8 and Nov. 4, at 61° + 48°; and on Oct. 8 and Nov. 7, at 77° + 31°; near μ Persei, and β Tauri.
....	D. (77) 109................	Aurigids; the radiant not very exact in September, and (?) double in October. A shower of swift ↓s with streaks, max. Sep. 16, 87° + 34°, near θ Aurigæ, ten ↓s, Sep. 7–16, D. 95.
Slow bright meteors.........	D. (77) 115..................	A fine rich shower; new; radiant exact.
Rather slow meteors	D. (77) 86	An active shower in October; and near the same place less strongly in July, August and September.
Very rapid, with streaks...	D. (77) 113..................	Radiant exact; extremely well-marked; certain shower, = ☄ 1825 I. ☋, 133° + 77°, Oct. 7.
Very rapid meteors	D. (77) 99	A very rich shower. = T. 82, Oct. 8, 14, and Nov. 7, 107° + 12° to 101° + 7°; and Schm., October, 108° + 12°, November, 113° + 14°. Distinct from Gemellids of October and November, with decl. + 25° to 30°, D. 106, 145.
Short and very rapid	D. (77) 97	Seen also in September (4–16, ten ↓s); very exact in October; an active shower in November.
Exceedingly swift meteors Not often with streaks.	D. (77) 118..................	Exact; very active shower Oct. 16th, $3^h\ 40^m$—$4^h\ 40^m$ a.m. Horary meteor-frequency in that hour, 40 or 45; on the morning of Oct. 17, 25; Oct. 18, a.m., 35!
....	D. (76) 110..................	An active shower; seen by several other observers. Four ↓s from same radiant and five from a neighbouring one at μ Ursæ (D. 90, 1878); seen also on Sept. 15–16, 1877.
23 of the 53 left streaks; swift white meteors; none = 1st mag.	H. Corder	Max. Oct. 18, 12^h–$3^h\ 30^m$ a.m. Horary meteor frequency on the 17th and 18th a.m. About 20.

A LIST OF REMARKABLE METEOR SHOWERS

Date, and (Horary or) Total Numbers				Position or Radiant-point		
Maximum Date	No. of ↓s	Total Duration	No. of ↓s	α	δ	By the Stars
1877. Oct. 17	(22)	Oct. 15–20	57	92	+15	ξ Orionis.................
Oct. 8 and	8	....	...	47	+28	Musca.....................
Oct. 31–Nov. 1.	13	Oct. 28–Nov. 13......	31	43	+22	ε Arietis ....
Nov. 5	Many	Oct. 28–Nov. 13......	14	102	+73	Near *p q* Camelopardi
Nov. 25......	...	and Nov. 27	9	24	+45	Near γ Andromedæ ...
Oct. 31–Nov. 4.	...	Oct. 28–Nov. 13......	9	40	+77	Taraudus ....
Nov. 10–13	5	....	...	148	+24	*x* Leonis..................
Nov. 13	(20 or 30)	....	...	....		Leo ....
Nov. 13......	7	....	...	146	+26	Near μ Leonis ....
Nov. 27......	6	and Nov. 25	+2	28	+46	Near γ Andromedæ ...
Nov. 29......	...	Nov. 25–Dec. 13 ...	9	285	+71	Near κ Cephei ....
Dec. 1–13...	9	....	...	109	+33	Near α Geminorum ...
Dec. 8	40	Dec. 8–12	8	145	+7	Near π Leonis ....
Dec. 10......	(About 20)	Dec. 9–12	...	107	+35	Between α and θ Geminorum; rather diffuse.

OBSERVED DURING THE YEARS 1877–78—*continued.*

Appearance of the Meteors	Observer or Reference	Comparison with earlier observations, and with Comet Showers; and Remarks
3 = ♃; 3 = 1st mag.; the rest, 3rd–4th mag.	D. (77) 89	Max. Oct. 18, $3^h\ 37^m$–$4^h\ 44^m$ a.m. (four bright ones together at $4^h\ 28^m$ a.m.). Seen also Sept. 15, 16 (eight ↓s); radiant very exact; sub-radiant of seven ↓s at 86° + 8°, = T. 79, Oct. 8.
Short quick meteors......... Rather slow meteors	D. (77) 122............	Seen only on Oct. 8, at 46° + 26°, Oct. 15, 1876; active, twenty-six ↓s Sept. 20–Oct. 25; D. 24, 1877. Radiant exact; a very rich shower. '*Muscids.*'
Very swift meteors	D. (77) 117.................	Also Oct. 2–19 (nine ↓s); a rich shower; radiant exact. (= S. Z. 163, and Gruber, xvi.)
Meteors very slow	D. (77) 142.................	The *Andromedes*; strongest shower on the 25th; feeble on the 27th. An exact radiant of four swift ↓s, D. 159, at 54° + 48° on the 27th. = Weiss, 52° + 49°, Nov. 27, 1872.
Rather slow meteors	D. (77) 143.................	Radiant exact; a new shower; suspected also in December.
Very rapid meteors, with bright white streaks.	D. (77) 149.................	A feeble return of the *Leonids*, their short tracks near Leo's "sickle" (two in two hours on each morning of the 10th and 14th, and one on the 14th seen by Mr. Greg) pointed out the radiant most exactly.
A few = 1st mag. stars, with streaks lasting several seconds.	B. Vail, C. P. Carr; 'Am. Jour. of Sci.' Jan. 1878.	Fifty-four ↓s in $1^h\ 50^m$, between $1^h\ 55^m$ and $3^h\ 45^m$ a.m., Nov. 14; nearly all *Leonids*. Seen at Bloomington, Ind. Sky after 2^h a.m. quite clear. D. Kirkwood.
1 = ♃, streak 3 secs., the rest small.	T. W. Backhouse	Radiant pretty exact; seven Leonids and eight other meteors in $1^h\ 20^m$ of clear watch, between $2^h\ 30^m$ and $6^h\ 15^m$ a.m., Nov. 14.
1 2nd, 1 3rd mag.; the rest very small, slow short-pathed meteors.	T. W. Backhouse	Twelve meteors (of which six Andromedes) in about one hour, Nov. 27, p.m. Only two ↓s (both Andromedes) seen in a short watch on the 25th, p.m.; radiant not very exact.
Swift, white meteors	D. (77) 157.................	An active shower, Nov. 29, p.m. (seen also, D. 121, Oct. 2–18). No Andromedes in three hours on this date.
Rapid, short meteors	D. (77) 151.................	Geminids; a few seen on Dec. 6, 8, 10, and 12; none in $1^h\ 15^m$ on Dec. 14, a.m.
Very swift meteors, with streaks.	D. (77) 153.................	Radiant exact; a strong max. on Dec. 8. At 148° + 2° in Nov.–Dec., 1876, = ☄ 1813 I. ☊ (?).
Short and small (one or two only = 1st mag. *), and seldom leaving streaks.	H. Corder	Greatest horary number (20 or 25) on Dec. 10, $10^h\ 30^m$ to $11^h\ 30^m$ p.m.: less marked on Dec. 9 than a contemporaneous shower of long bright ↓s with streaks, from ι Geminorum, 108° + 28°, scarcely seen on Dec. 10; overcast on the 11th; a few Geminids on the 12th.

A LIST OF REMARKABLE METEOR SHOWERS

Date, and (Hourly or) Total Numbers				Position of Radiant-point		
Maximum Date	No. of ↓s	Total Duration	No. of ↓s	α	δ	By the Stars
1877, Dec. 11......	(About 35)	Nov. 27–Dec. 13 ...	...	104°	+39°	Near θ Geminorum ...
1878, Jan. 1	(About 30)	....	17	222	+55	Near θ Boötis ....
April 20–22	12	....	...	272	+32	Near 99 Herculis ......
July 25–26	...	....	...	332	+37	Near α Lacertæ.........
[1875, Aug. 2* ...	Many	....	...	314	+ 41·5	o Andromedæ...........
July 27–29	22	July 26–31	+28	341	−13	Near δ Aquarii ....
July 31	21	July 26–Aug. 1	+38	32	+53	Near 65 (P. Bode) Andromedæ.
Aug. 10......	5	....	...	6	+37	Near π Andromedæ ...
Aug. 10......	(About 50 ?)	[$10\frac{1}{2}^h$ p.m.–3^h a.m.]	130 Pers + unconf.	42·5 and	−54	h Persei ....
[$2\frac{1}{2}^h$–3^h a.m.]	33, 26 of them Perseids	....	...	44	+59	B Camelopardi ......
Aug. 10...... [$2\frac{1}{4}^h$–$3\frac{1}{4}^h$ a.m.] Average	97 (44) (28)	[In 4 hours] ...... [Max. in 1 hour]	+16 unconform.	43	+56	h Persei ....

* In the above quoted place of these Reports describing the July—August 'Lacertid' showers and the showers observed by Mr. Hind at o Andromedæ, August 2, 1875, the place of Schiaparelli's shower, 123, July 30, with which it

OBSERVED DURING THE YEARS 1877–78—*continued.*

Appearance of the Meteors	Observer or Reference	Comparison with earlier observations, and with Comet Showers; and Remarks
Meteors short, white, chiefly 1st and 2nd mag., slightly trained.	R. P. Greg	Radiant of thirty tracks mapped on Dec. 9 and 11; shower increased in brightness and precision of radiant to Dec. 11, p.m. (appearing sometimes one per min.); no sub-radiant seen.
Bright meteors, without streaks; rather short and quick.	A. S. Herschel	A bright shower, 4^h–4^h 30^m a.m. Jan. 2; none seen in half-an-hour a.m., Jan. 1 and 3; radiant diffuse, not very exact.
Short paths, leaving streaks	W. F. Denning, 'Monthly Notices' R.A.S., vol. xxxviii. p. 396.	Very exactly defined radiant of several foreshortened paths (☄ 1861 I. at 270° + 32°). In two-hour watches, six Lyrids on April 21, and three Lyrids each on April 20 and 22, p.m.
Bright slow meteors; long paths.	W. F. Denning	A rich shower, with very exact radiant-point; confirms S. Z. 98, July 18, 332° + 35°. [See the next shower].
One bright = α Lyræ	J. R. Hind (these Reports, vol. for 1875, pp. 215, 216).	Many $\downarrow$s, between 9^h 30^m and 11^h p.m., with most distinct radiant-point. Confirms S.Z. 123, July 30, 345° + 40°.
Slow; long paths, 15°–20°; no streaks.	W. F. Denning	A fine bright shower, July 28, p.m. (= T. 43, July 27, 28, 1870, 340° − 14° to − 19°).
Quick; short paths, about 7°, with streaks; 3 $\downarrow$s = ♃, several 1st mag., among the 59 observed.	W. F. Denning	A short rich shower with precise radiant-point; max. July 31, p.m. (= Schm., Aug. 3–12, 31° + 55°). Only five or six true Perseïds seen on July 31 and Aug. 1.
....	W. F. Denning	Confirms G. 103; also observed 1877, Aug. 3–16; = ☄ 1780 II., Aug. 14, 3° + 38° (?).
Many very bright, with streaks; 4 = ♃, others = ♂, and Sirius.	W. F. Denning, 'The Observatory,' vol. ii. p. 165.	The Perseïds; watched all night till after moonset; less plentiful than on Aug. 10, 1877. The radiant, from numbers of foreshortened paths near it, distinctly double. On the 7th, six Perseïds among sixteen $\downarrow$s; radiant, 42° + 57°, inexact.
Of the $\downarrow$s mapped, 1 > ♀, 1 = Sirius, 9 = 1st mag. stars, all leaving streaks.	H. Corder, Chelmsford. 'The Observatory,' vol. ii. p. 160.	Radiant of 40 or 50 remarkably accordant tracks; short $\downarrow$s near the radiant gave 45° + 57°; and one was stationary at 47° + 58°. (Sky overcast on the 9th and 11th; sixty-one $\downarrow$s in three hours and a quarter, on Aug. 7, many Perseïds, radiant 43° + 55°).

agrees exactly, is wrongly given as 335° + 40°. The shower observed by Mr. Denning on July 25–26 confirms a new member of Schiaparelli's 'Lacertid' group S.Z. 98, 103, 106, 123, July 18–30 (average position 337° + 41°).

bright as 1st mag. stars. The largest were greenish, the larger 1st mag. ones orange, and the lesser yellow, the remainder being white. After the night of the 11th no further view of the shower was obtained, the sky being continually overcast.

Observations at Bristol, by Mr. W. F. Denning.—The sky was overcast on the nights of the 9th and 11th. The appearance of the shower on the 10th (as described in last year's Report) was somewhat notable, but not above an average intensity of the Perseïd shower. On the 12th the abundance of the meteors was much less than on the 10th, and did not greatly exceed the rate of their appearance on the 7th. In long watches on several of the nights of the shower's continuance, which, excepting August 5th, were fairly favourable for observations, the following average horary numbers of shooting-stars were seen, the average rate of appearance of the unconformable meteors being, with little variation, during the time, about fifteen per hour:—

Date, 1877, August	3	4	5	7	10	12
Average horary frequency of meteors	16	18	(11)	21	71	29

Thirty-two Perseïds and 159 unconformable meteors were seen on the nights of August 3rd to 7th, showing the comparative scarcity (1 : 5) of the meteors of the periodic shower, until very near the principal date of its occurrence. Mr. Denning's observations during the last few annual August showers have, in fact, established (as the results obtained in this year's shower, to be described below, will presently disclose most clearly) that reputed appearances of the Perseïds before the 1st of August are pretty certainly to be ascribed to some neighbouring showers in Perseus, one at least of which is a very rich one, with a centre at $32°+53°$ near θ, only 7° or 8° distant from that of the true Perseïds near η Persei. A star-shower of considerable intensity and restricted to a few nights only in its total duration proceeded, in 1878, from this radiant-point on the night of July 31st. Two other Perseus showers in July, 1877 (as was recorded last year in these Reports, for 1877, p. 159), were also seen by Mr. Denning at $36°+47°$, and $47°+45°$, with apparent resemblances in the positions of their radiant-points to the orbits of the comets 770, ☋, and 1764, ☋. Further observations of the last of these July showers near ϵ Persei, were obtained in August and September, 1877; and during the long time of its visibility, apparently, in these three months, its meteors, like those of the other circum-Perseïd showers just mentioned, were certainly distinguishable by Mr. Denning from the true Perseïds of August 10th. Of these latter he noted 385, together with 569 meteors unconformable to the true Perseus radiant-point, during the interval from July 6th to August 23rd.

Continuing his observations in September, Mr. Denning recorded in July, August, and September, 1877, the paths of 1205 meteors, and deduced from them eighty-nine radiant-point positions. Of these about twenty (chiefly in July and August, between the 3rd or 6th and the 16th or 17th days of those months) were duplicate determinations belonging, apparently, to repetitions of a single shower. A radiant-point near α Cassiopeiæ, two in Andromeda, two in Cygnus, and two others in Lacerta and Aquarius (see the accompanying list), were of this description. One of these, near α Cygni, at $315°+50°$ presents some resemblance in its position to the orbit of Coggia's comet, 1874 III (radiant-point, July 21st,

313°+48°), but the comet's passage through its descending node was at such a distance (0·285 of the sun's distance from the earth) within the earth's orbit that the possibility of this meteor shower and the comet having any real connection with each other is extremely doubtful. Marked showers east of Perseus were noticed in Camelopardus, Perseus, and Aries during the morning watches of the Perseïds on August 10th and 12th (11th and 13th, a.m.), 1877, of which Mr. Denning has since obtained by observations, and by extensive reductions of other observers' meteor-catalogues, very excellent and abundant corroborative indications. Among the showers noted in the second week of September, were two active radiants —one near ξ Persei, and one in Ursa Minor,—accompanying the former of which, some traces, apparently of the October Aurigids, near δ Aurigæ, were visible, with a maximum on September 5th. On the mornings of September 15th and 16th, shooting-stars were very numerous, and Mr. Denning noted several meteor showers with apparently new radiant-point positions * from the paths of 117 meteors recorded in nine hours.

A somewhat extraordinary apparition of a meteor shower in September last, described as related to him by an observer at Bloomington, Inda., by Professor D. Kirkwood in the 'Scientific American,' (transcribed in the 'London Iron Trade Exchange' of October 6th, 1877), was as follows: "A few minutes after 10 o'clock on Friday evening, September 7th, 1877, Mr. John Graham, of Bloomington, Inda., had his attention arrested by a sudden light in the heavens, and on looking up he saw a stationary meteor between *Aquila* and *Anser et Vulpecula*, about R.A. 295°, decl. 15° N. It increased in brightness for a second or more, and disappeared within less than ½° east of the point at which it was first seen. Immediately after the extinction of the first, three others, separated by intervals of three or four seconds, appeared and vanished in the same place, with the exception that one disappeared about as much west of the radiant as the first did east of it. Mr. Graham's curiosity was excited, and he continued to watch until after an interval of a few minutes a fifth meteor corresponding in appearance to the preceding was seen in the same place. The meteors were about equal to stars of the first magnitude. The fact indicates that a stream of meteoric matter was moving at the time almost exactly towards the observer. Two or three isolated cases of stationary meteors have been recorded; the phenomena of the 7th inst. are, however, quite extraordinary. I have stated the observations as given me by Mr. Graham, who pointed out the position in which the meteors were seen." On the disappearance of streak-leaving meteors, when seen perfectly stationary, it not unfrequently happens that the rekindling of the streak, which is a singular property of the luminous vapours left on a meteor's track (see the last vol. of these Reports, p. 169, for similar examples), presents the appearance of a second meteor shining forth, a second or two later than the first one at the same place. In the case of extremely large meteors, whirls and contortions of the vapours on its track may perhaps concentrate their light into several such rekindling centres, since the observer's line of sight is at the same time directed along scores of miles of their very feebly phosphorescent

* A list of these new a.m. showers given by Mr. Denning in 'The Observatory,' vol. ii. p. 164 (Sept., 1878), is as follows: At 156° + 41°, 130° + 46°, 101° + 11°, 88° + 17°, 87° + 34°, and 73° + 14°. They are nearly all showers (D. 90, 110, 99, 89, 95, 102) seen also in October.

substance. Perhaps the extraordinary succession of stationary meteors seen by Mr. Graham may admit of some such intelligible explanation.

During evening watches on October 2–4 many fine meteors were again observed, Mr. Denning counting 127, and noting numbers of their paths, in intervals extending together over 13¾ hours.* Two of the brightest were small bolides, about as brilliant as Venus and Jupiter, which, together with several others diverged on the night of October 22nd, from a radiant-point in the head of Bootes, at 225° + 52°. The brightest one of the shower left a nebulous light streak at its place of explosion and disappearance visible for 3½ minutes, and drifting some 5° from its first position before it disappeared. On the following night another Venus-like meteor leaving a light streak for 15 seconds shot from the direction of a radiant-point of less marked activity (D. 92, 1878, at 167° + 75°) midway between the 'Pointers' and Polaris. The next conspicuous radiant-point observed was that of many pretty bright meteors on those two nights, and on October 4th, from the direction of an exceedingly well-defined centre in the head of Camelopardus, at 133° + 79°. The shower remained visible on some following nights, and was an extremely distinct and certain shower on the first nights of its maximum display. It agrees in date and position so very closely with the radiant-point of a stream moving in the same orbit with the comet 1825 II., ☋ (at 133° + 77°, October 7th). that although this orbit passed just transversely to the plane of the ecliptic, about ten millions of miles inside the earth's orbit, at the shower date, yet the certainty and exactness of the meteor shower leave scarcely a reasonable doubt of the meteor-shower's connection with the comet. The agreement is supported by meteor-showers of Heis (N_{16-18}) close to the cometary radiant-point in September and October; and if the apparent identity can be re-established and confirmed by new precise determinations, it will afford a very convincing argument that the materials of comet's tails may give rise to meteor-showers, or that at least the orbit of a meteor-shower, shown to agree in every other element with a non-periodic comet's orbit, may yet differ very largely from the comet's orbit in its perihelion distance. Another radiant-point near Polaris was active on the same nights, but lying on the opposite of the north pole, in Cepheus; and in this position a nearly continuous shower appeared to be situated from July to October.

A long watch for shooting-stars was kept by Mr. Denning on the night of October 8th, 105 meteors being seen, and 95 of their tracks recorded in ten hours, the sky throughout being brilliantly clear. The numbers seen in the four hours preceding 11 o'clock were three, six, nine, seventeen; the numbers seen between 10^h and 11^h being the greatest number recorded in one hour during the night. A note received soon afterwards from Mr. T. W. Webb informed Mr. Denning of a reported appearance at Hay, S. Wales, of many falling stars between 10^h 15^m and 10^h 45^m p.m. on the night of October 8th, as an occurrence which had attracted some attention. The meteor frequency was quite confirmed by Mr. Denning's observations; but it is yet remarkable that it did not proceed from an outburst of any individual or special meteor-shower, as the meteors came from many radiant-points, none of which, during the time indicated, showed an exceptionally great activity.

* For particulars of these nights' observations the Committee is indebted to long and full description in a Bristol newspaper, communicated by Mr. Denning.

Simultaneous showers from Monoceros, Musca, Triangulum, β Tauri, μ Persei, and δ Aurigæ furnished, in fact, during the night, scarcely more than ordinary numbers of about six or ten meteors each. At $11^h\ 56^m$ a bolide, about twice as bright as Venus, shot obliquely downwards from the direction of one of these radiant-points near β Tauri, close to the east horizon, and it appears not improbable that it was identical with one of two bright fire-balls seen on about the date of this exceptionally clear October night in France.* Six meteors as bright as Jupiter, and two as bright as Venus, besides this brilliant bolide, had been recorded by Mr. Denning among the many shooting-stars which he observed on the nights of September 15 to October 8. A meteor-shower in Lynx (with a radiant-point at *g* Lyncis, also very active in November), was seen about the middle of October, which was very well defined, and, appearing to be new, may only have become visible last year, or since the date of Mr. Greg's last general catalogue in 1875-6.

The Orionids of October, 1877.—A very successful series of observations of this meteor-shower was obtained between October 16 and 20 (a.m.) by Mr. Denning; and at Writtle on October 17 and 18 (a.m.) by Mr. Corder. Between $3^h\ 40^m$ and $4^h\ 40^m$ a.m. on October 16th meteors were falling at the rate of forty or forty-five per hour; but not from Orion, nor from any solitary radiant-point, although one in Cancer, at $133° + 20°$, was extremely active. On the mornings of October 17th and 18th the horary numbers were also exceptionally large, twenty-five and thirty-five; and on these dates, as well as on the 19th and 20th (a.m.) the Orionids had become much the most considerable and conspicuous shower. At their greatest rate of frequency on the 18th (and also on the morning of the 19th) their numbers were nearly equal to those of the sporadic or unconformable meteors of other simultaneously prevailing showers, as the following summary of his observations on the above mornings by Mr. Denning will show briefly in a tabular arrangement:—

"Numbers of the Orionids, October 17–20 (a.m.) 1877, for one observer looking towards Orion (only the times of watch for the Orionids are stated):—

1877 Oct.	Duration of Watch; a.m. From	To	Length of Watch	Number seen: All Meteors	Number seen: Orionids	Calculated Horary Numbers: All Meteors	Calculated Horary Numbers: Orionids	State of the Sky
17	1^h	3^h	2^h	41	13	27	9	Very clear.
18	2	5	3	70	33	35	16	Slight fog.
19	$4\frac{1}{4}$	$5\frac{1}{4}$	1	19	9	25	12	Fog; stars dim.
20	5	$5\frac{1}{2}$	$\frac{1}{2}$	14	2	37	5	Very clear.
17–20	1	$5\frac{1}{2}$	$6\frac{1}{2}$	144	57	31	$10\frac{1}{2}$	

"Maximum, October 18th, $3^h\ 37^m$ to $4^h\ 44^m$, a.m.; calculated number of Orionids, twenty-five; calculated horary number, twenty-two. At $4^h\ 28^m$ four bright ones appeared almost simultaneously in Ursa Major.

* A notice of two such fireballs appeared in the 'Bulletin de l'Association Scientifique de France,' vol. xxi. p. 224 (Jan. 6th, 1878).

"Radiant-point, very accurate, at 92° + 15° (fifty-seven meteors).

"A subradiant-point, strongly suspected at 86° + 8° (seven meteors).

"Of fifty-seven Orionids, forty-seven left streaks. Magnitudes, 3 = ♃, 3 = 1st mag. stars; the rest generally 3rd–4th mag. stars. Observer, W. F. Denning."

Besides the shower in Cancer, contemporaneous showers in Lynx, and Ursa Major, with the Orionids, were found to be very active.

With a small number seen on other days, Mr. Corder noted fifty-three Orionids on the mornings of October 17th and 18th. On the latter morning their horary rate was fourteen for one observer. Few were observed before midnight, and the shower seemed to slacken after 3^h 30^m a.m.; while, on the other hand, a shower of slow-moving meteors from *o* Piscium, which continued all night, was especially active towards morning, when its radiant was in S.W. The horary number of meteors of all kinds on the two mornings was about thirty for one observer. The radiant was at 89° + 18° on the 17th, and at 95° + 17° on the 18th, showing apparently a movement or displacement of some degrees. No meteors equal to the 1st mag. stars were seen, but twenty-three Orionids left streaks; they were white, their speed was great, and the streaks were rather persistent. After the maximum of the Orionids had passed, one of the Ursids occurred, but with a radiant so diffuse as not to admit of being well determined.

The following table briefly represents the number of hours of observation, a.m. and p.m., and the numbers of meteors seen, and of meteor-showers recorded by Mr. Denning during the months of July–October (until October 20th), 1877. The meteor-showers are extracted from 1113 registered meteor-tracks, and 385 Perseïds, counted in August, are not included among the total numbers seen:—

Month	Hours, a.m.	Meteors seen	Hours, p.m.	Meteors seen	Total Hours	Meteors	Meteor Showers	Recurring Showers
July...........	$12\frac{1}{2}$	125	$11\frac{1}{4}$	72	$23\frac{3}{4}$	197	22	15
August	$11\frac{1}{4}$	185	$16\frac{1}{2}$	200	$27\frac{3}{4}$	385	31	
September ...	12	146	10	92	22	238	35	5
Oct. (to 20th)	$22\frac{1}{4}$	338	$21\frac{1}{4}$	184	$43\frac{1}{2}$	522	47	20
July–Oct. 20.	58	794	59	548	117	1342	135	40

During the last few nights of October, and on November 1st, a bright and abundant shower of "Muscids," with an exact radiant-point near ε Arietis nearly agreeing in radiant-position with the "Muscids" of September 20th–November 17th, 1876, and with the maximum appearances of that shower on October 15th, 1876, and October 8th, 1877, was observed, furnishing many bright meteors; and besides these notes of its marked display by Mr. Denning, two small bolides, about as bright as Venus, belonging apparently to the same shower, were seen at Birmingham, and at Sunderland, on the evening of November 4th, 1877, by Mr. Wood and Mr. Backhouse.

Of the various Taurid showers in October and November, 1877, very few and imperfect indications were observed, although the weather was not always very favourable for their detection. At Writtle, the state of the sky only permitted shooting-stars to be recorded on three nights in the first half of November, when Mr. Corder saw twenty-four, forty, and forty-three meteors, "mostly Taurids and Ursids, the latter (as also

in October) an inextricable mixture of radiants and subradiants." Mr. Denning wrote, at Bristol: "The Taurids I, this year, seem to have been an utter failure; of 508 meteors registered between October 14th and November 14th, only about fifteen can be referred to that shower; yet I have been looking a good deal towards Taurus!" No well-marked dates, nor even radiant-points of the 'Taurid' shooting-stars, in 1877, were accordingly observed.

The *Leonids*, and *Andromedes* in 1877.—Of the Leonids distinct but yet feeble traces were recorded by Mr. Denning on the mornings of November 11th and 14th.* Mr. Backhouse, at Sunderland, registered seven of their paths, with those of eight other shooting-stars, in 1^h 20^m of clear watch, ending at 6^h 15^m a.m. on the morning of November 14th, one as bright as Jupiter, leaving a bright bluish-green train for three seconds, where it shone out brightly near the end of its course; the number and well-marked radiant-point of these meteors clearly denoting a slight but yet very distinct return of the November Leonids. It was also seen in America, as the following notice, extracted from the 'American Journal of Science' (3rd ser., vol. xv., p. 76), in 'The Observatory' (vol. ii., p. 64, June, 1878), describes:—

"The November meteors.—Professor Kirkwood writes in the 'American Journal of Science,' of January, 1878, that fifty-four meteors were counted by two observers (B. Vail and C. P. Carr) at Bloomington, Inda., on the morning of November 14th, 1877, between 1^h 55^m and 3^h 45^m a.m., being at the rate of thirty per hour. Nearly all were Leonids, a few being as large as first magnitude stars, with trains which lasted for several seconds. The appearance of so large a number, ten or eleven years after the maximum displays of 1866-67, is quite unexpected. The early part of the night was cloudy, but before 2^h a.m. the sky became quite clear." The interval of Mr. Backhouse's watch ending soon after 6 o'clock, terminated about an hour before that of the American observers' watch began. A pretty bright commencement of the rather stronger Leonid display recorded in America, as this paragraph describes, must accordingly, during Mr. Backhouse's observations at Sunderland at a slightly earlier hour, have been the general character and appearance of this meteor-shower during the early portion of its time of apparition, in which it appears that a somewhat notable return of the Leonids in November, 1877, was visible in America.

Two apparitions of the November Andromedes, about equal in intensity to that of the Leonids, were seen on the nights of November 25th and 27th, 1877, by Mr. Denning and Mr. Backhouse. At Bristol Mr. Denning relates that, "Observations of the Andromedes were commenced on the evening of November 25th. Between about 5^h 40^m and 7^h 10^m ($1\frac{1}{2}$ hour) sixteen meteors were seen, of which seven, or nearly one-half, were Andromedes, with a radiant-point sharply defined at $24° + 45$ (near χ, ω Andromedæ). They were very slow orange-coloured meteors with short paths. On the evening of November 27th, between about 9^h and 10^h 30^m, the sky was watched for $1\frac{1}{4}$ hour, and ten meteors were seen, of which

* 1877, Nov. 11, between 12^h 0^m a.m. and 2^h 35^m a.m.; in $2\frac{1}{2}$ hrs., 2 Leonids and 30 unconform. ↓s seen; sky very clear.

1877, Nov. 13, between 12^h 11^m a.m. and 1^h 57^m a.m.; in $1\frac{1}{4}$ hrs., *no Leonids*, 21 unconform. ↓s seen.

1877, Nov. 14, between 1^h 19^m a.m. and 3^h 22^m a.m., in 2 hrs., only 2 Leonids and 24 unconform. ↓s seen; slight fog; no clouds.—W. F. Denning.

two only conformed to the radiant-point of the Andromedes. Thus, so far as my brief observations allowed me to determine, the shower was more actively in progress on November 25th than on the 27th, in the proportion of about three to one.

"On the evening of the 29th a watch was maintained for three hours, and twenty-seven meteors were seen, of which *none* were from Andromeda. There was, however, an active display of swift white meteors with streaks from a radiant point at κ Cephei, at 185° + 71°. On December 1st and 2nd observations extended over four hours (twenty-eight meteors), but no more Andromedes were observed. So far as I can judge the shower was at its best on November 25th. Cloudy weather prevented work on November 26th."

In a watch of little more than 20^m (at 7^h 24^m and at 7^h 42^m p.m.) on the evening of November 25th, Mr. Backhouse registered two shooting-stars at Sunderland, both apparently Andromedes. On the night of November 27th, in a watch of 50^m, equivalent to about three-quarters of an hour in a cloudless sky (about one-tenth part of the sky being on an average overcast, and slight moonlight prevailing towards the close), ending at 11^h 30^m, Mr. Backhouse observed eight meteors, corresponding to an horary rate of frequency of about eleven. Twelve shooting-stars were registered before midnight. Of these six (one rather doubtful from its swiftness) were Andromedes, with short courses, not far from the radiant-point, which was sharply marked (by all but one of their paths) at 28° + 46°. Only two were as bright as second or third magnitude stars, of yellow colour; their motion was slow, and the nucleus of the brightest had a short tapering tail.

From these descriptions it appears that on both the nights of November 25th and 27th, 1877, the horary frequency of the Andromedes was occasionally as great as that of the contemporaneously occurring sporadic or unsystematic shooting-stars, and that their radiation on each of those nights was sufficiently exact to denote a distinct although a very feeble reappearance of the Bielan shower.

The *Geminids* of December 10th—11th, 1877.—A good view of this annual shower's appearance on the nights of its greatest intensity was obtained by Mr. Greg, who watched the progressive increase of its brightness from November 27th. The meteors increased in numbers and in accuracy of radiation until the display reached its maximum on the night of December 11th, when at one time they certainly succeeded each other, for one observer, at the rate of one a minute; and their average horary rate for one observer on that evening was about thirty-five. Their apparent paths, even at a distance from the radiant-point were extremely short (not more than 5°), and but little marked with streaks, rendering it difficult to fix their radiant-point exactly. This centre of nearly thirty tracks, mapped on the 9th and 11th, in a somewhat restricted region of the sky near Ursa Major, was at 104° + 38°, four or five degrees north of the line joining α, θ Geminorum, and in rather higher declination than has hitherto been usually observed, confirming the supposition which Mr. Greg has been led to entertain from former observations of this shower, of an elongation of its radiant-point in declination between about + 30° and + 40° N. decl. The meteors did not vary much in colour or in brightness, presenting in general the appearance of first or second magnitude stars, bright white, and moving with considerable velocity. Although Mr. Greg's attention was specially directed to determining the positions of any co-existing

radiant-points which might at the same time be observable in the constellation Gemini, none such could be detected.

Mr. Corder's and Mr. Denning's observations of the Geminids near Chelmsford, and at Bristol, relate principally to the shower's appearance on the nights of December 9th, 10th, and 12th. It was on the former date that its meteors first appeared to Mr. Corder to be growing numerous, only occasional Geminid-meteors having been visible earlier in December, when the sky was favourable for observations. "On the 9th, however, nearly twenty were seen in about three hours, the first hour (from 8^h to 9^h p.m.) producing very few meteors of any kind. One Geminid, as bright as Sirius, of a beautiful pale emerald-green colour, left a streak at disappearance. Simultaneously with the true Geminids a meteor system was active, diverging from ζ Geminorum, supplying finer and longer meteors. One of these was seen at 8^h 13^m in the north-west, as bright as Jupiter, of a bluish mauve tint, leaving a long but narrow streak. At 11^h 58^m a similar one shot upwards to Polaris, as bright as Sirius, and of the same mauve colour as the former one.

"The characteristic of these meteors seemed to be their length and the brightness of the streaks mostly left upon their tracks, while the true Germinids were short, and seldom streak-leaving. Their radiant was at $108° + 28°$, and this meteor-stream had ceased almost entirely on the following night.

"On the next evening (December 10th), between 7^h and 11^h 30^m, sixty-five meteors were seen, forty of which were Geminids. The hour from 10^h 30^m to 11^h 30^m produced twenty-five meteors, almost all from the principal radiant, Only one was equal to a first magnitude star, and it was pale green. Very few of the Geminids left streaks, and they were mostly very short and small.

The radiant was diffuse, perhaps owing to the difficulty of mapping them in the barren part of the sky between Gemini and Polaris where they frequently appeared. Many radiated from near Castor, and others from nearer to θ Geminorum; the mean position [nearly midway between those stars] being at $107° + 35°$.

"A few Geminids were seen on the 12th; the 11th being quite overcast."

Some further account of the shower's prevalence on the latter date, and on some earlier days in December, are supplied by Mr. Denning's notes, who wrote from Bristol:—" On the night of December 6th, I found meteors wonderfully scarce; only thirteen in three hours (!); and only two of them were Geminids. Of twenty-three meteors seen in two hours and a half on the evening of the 8th and morning of the 9th, four were Geminids. On the morning of the 11th, between 5^h 10^m and 6^h 10^m a.m. (1^h) eleven meteors were seen, including two Geminids. On the morning of the 13th (between storms and clouds), I looked out for about three-quarters of an hour between 4^h 45^m and 5^h 45^m a.m. Meteors were falling very fast, and I saw twenty-eight altogether, of which six were Geminids.* In one and a quarter hour, between 5^h 15^m and 6^h 30^m a.m. on the morning of December 14th, twenty-one meteors were seen, but no Gemi-

* Among these meteors a few fine shooting stars with streaks and very swift long paths, diverged from a point on the equator in R.A. 166°. This agrees with a position (T. 2) given by Captain Tupman, although for a rather later date, at $160° + 3°$, Dec. 23–31st and $165° + 4°$, Jan. 8–10th.

nids. The watch on all these mornings was directed towards the eastern sky, not so much to observe the Geminids as to discover some new showers in Virgo, Corona, Boötes, &c., which are just visible before daylight in December; and of four of these which I observed I believe the following positions to be accurate, at 199° +19°, 221° + 43°, 230° + 33°, and 195° − 3° (December 11–14th, a.m., 1877).

"The radiant point of the Geminids was at 107° + 33°, with suspected neighbouring centres at 102° + 45°, 87° + 37°, and 111° + 23°. The meteors were slow near the radiant, but rapid when far from it. Their courses are not often marked with streaks, and are almost invariably short; in this and other particulars of the general appearance of the Geminids, I can clearly confirm Mr. Greg's remarks from my own observations of them both this year and last."

Star-showers of *January* and *April*, 1878.—Watches kept at several places in England for the meteors of January 1st–3rd were almost wholly unsuccessful, a cloudy and overcast state of the sky having prevailed everywhere on the dates of their expected appearance. Occasional glimpses of clear sky occurred in Kent, however, on the first three nights of the year, and the January shower was seen, at Hawkhurst, with some intensity on the morning of January 2nd, by Professor Herschel. Seventeen *Quadrantids* and three unconformable meteors were registered during the half hour beginning at four o'clock, a.m., at the end of which clouds formed and overspread the sky. The meteors were bright, two being equal to Jupiter or Sirius, and five or six equal to each of the first and second magnitudes of the fixed stars; the rest being as bright as third or fourth magnitude stars; occasional thin clouds, and a slight haze which dimmed the stars, perhaps concealed some meteors of the smallest magnitudes, and caused the radiant obtained from their recorded tracks to be a little diffuse. Its centre occupied a point at about 222° + 55° in quadrans, near θ Boötis. This point being nearly in the zenith, the meteors' courses were short and quick, and that of the brightest one appeared to be a little curved. They were yellowish-white in colour, and left no streaks or sparks. During a watch of half an hour on each of the mornings of January 1st and 3rd, when the sky was clear, no meteors of the Quadrantid shower were seen, the maximum of its display being accordingly confined to the morning of the 2nd.

The nights of April 19th–21st, 1878, were also very unfavourable for observations, but a slight return of the "Lyrids" was observed at Bristol on the nights of April 20th–22nd, by Mr. Denning. Three Lyrids and three meteors from a radiant near ϵ Herculis were seen in two hours, amid much cloud, on the 20th; and in the same time, with very clear sky, twenty-five meteors (six Lyrids) and twenty-two meteors (three Lyrids) were seen towards midnight on the 21st and 22nd. An abundance of meteors, and a continuance of the Lyrid shower on these latter nights is rare; and it seems to have been an exceptional feature of the shower in the present year. The meteors left streaks, and the paths recorded were nearly all foreshortened near the radiant-point, which was very exactly defined at 272° + 32°. This position, near θ and the star 99 (A_2 Bode) Herculis, is in 5° less right ascension than the Lyrid-centre (QH_2, 1874) found by Greg and Herschel, and agrees more exactly with the radiant of the Lyrid-comet 1861 I (at 271° + 33°), and with the position found in April, 1869, by Professor Schiaparelli from Dr. Karlinski's observations (at 267° + 35°), than other previous determinations; a feature also of the April

Lyrids of the present year in which their feebly pronounced display seems to have been somewhat peculiar.*

The next remarkable meteor-shower observations of the present year were those of the July and August shooting-stars, 1878. A distinct shower of Cassiopeiads of those months, coinciding with one already recorded by Greg, Heis, and Schiaparelli, at about 12° + 70°, was observed in July by Mr. Denning at 15° + 70° (thirty-five meteors). Towards the end of July, having, from foreign catalogues and other sources, obtained abundant indications of circum-Perseus and other contemporary showers of the great August epoch, Mr. Denning employed the finest nights after the moon's last quarter to verify them by his own observations. A meteor was thus observed on July 21st, of a shower near θ Persei (at 32° + 53°), of which Mr. Denning had anticipated the date and position from the following indications:—

July 6–17 (1877) ...	36° + 47°, 6 ↓s;	observed by W. F. Denning	Average position July 6–Aug. 13, 33° + 49°. (= Schmidt, Aug. 3–12, 31° + 55°.)
„ 25–31..............	32° + 51°, 25 ↓s;	in various foreign Catalogues	
„ 15–Aug. 2.........	30° + 47°, 10 ↓s;	in the Italian Catalogue, 1872	
and Aug. 6–12	34° + 50°, 3 ↓s;	in the Italian Catalogue, 1872	
„ 13...........	33° + 51°, 10 ↓s;	in various foreign Catalogues	

A strong maximum of this shower, quite confirming the correctness of Mr. Denning's anticipations of its reappearance, set in on the nights of July 26th–August 1st, exhibiting a perfectly defined radiant-point 3° or 4° south of the star-cluster χ Persei, at 33° + 52°. Forty-four meteors from this radiant-point were traced on the nights of July 30th, 31st, and August 1st, alone; and the whole number of meteor tracks recorded from it until August 1st was fifty-nine. The maximum took place on the night of July 31st, when twenty-one of its meteors were observed. They are short, swift, white shooting-stars, leaving streaks, and by their resemblance to the true Perseïds, or Perseïds I, from whose principal centre their radiant is only distant about six or seven degrees, these mock-Perseïds, or Perseïds II, have no doubt been mistaken, when abundant in July, for the earliest meteor-representatives of the true Perseïd display. The shower was of brief duration, and as short-lived in its departure as in approaching its maximum, for among forty-four meteors seen on the nights of August 7th and 8th, when the sky was again clear enough for observation, not a single meteor of this new Perseïd system was observed. Of the true Perseïds the first indications seen were five or six meteors, on the nights of July 31st and August 1st; and six meteors among sixteen, registered on August 7th, were Perseïds I.

* 'The April Lyrids and Contemporary Meteor-Showers,' by W. F. Denning: 'Monthly Notices' of the Royal Astronomical Society, vol. xxxviii. p. 396, May, 1878. A number of circum-Lyra showers for the great April-epoch, deduced from foreign observers' catalogues, together with some active shower-centres in April, observed by himself, are presented in this Paper by Mr. Denning. Among the latter is one suspected near δ Cassiopeiæ, which is perhaps identical with the centre of divergence of two detonating fireballs seen in Austria on April 10th, 1874, and April 9th, 1876, which Professor von Niessl found to be near ϵ Cassiopeiæ. (See the last volume of these Reports, p. 147.)

Another rich and important meteor-shower of bright shooting-stars with long slow courses, with a radiant point near δ Aquarii at $341° - 13°$, was seen by Mr. Denning on the night of July 27th, and many more were recorded from it on the two next nights, while on the last clear night of observations, on August 1st, its brief but notable and very active display had entirely disappeared. With the shower of Perseids II, this fine and conspicuous star-shower of δ Aquariads (already recorded, T. 43, on the same date and with the same radiant position, by Captain Tupman, in the year 1870,* and seen in August, 1877, at the same place by Mr. Denning), deserves to be ranked with the Orionids, Geminids, May Aquariads, and a few other distinct, but not yet much studied, meteor systems, among the major, or special star-showers of the year; and to have its date and radiant-point more frequently examined to discover if its appearance is annual, or subject to regular or irregular fluctuations.

The *Perseid* shower of August 10th, 1878.—The brightness of the moon until after midnight, followed immediately by that of approaching day-break, detracted from the apparent abundance of the shower. The sky was quite overcast on the nights of August 9th and 11th; but cloudless on the 10th. At Bristol Mr. Denning counted about 130 meteors in a watch of four hours and a half, between $10^h\ 30^m$ p.m. and 3^h a.m.; thirty-three meteors being counted in the last half-hour, of which twenty-six were Perseïds. This rate of appearance was less than the half-hourly number (forty-two or thirty-three Perseïds and nine unconformable meteors), between $12^h\ 30^m$ and $2^h\ 30^m$, a.m., on the night of August 10th–11th, 1877, although fog, haze, and clouds then slightly dimmed the stars. The shower's appearance this year was accordingly less active than at the corresponding time in August, 1877. The paths of seven Perseïds, as bright as the planets Mars and Jupiter, and of five equal to first magnitude stars, were mapped, and several other bright Perseïds were seen, all of which left persistent streaks. Attention was especially given by Mr. Denning to mapping the tracks of Perseïds near the radiant point, and of these the foreshortened paths traced backwards were found to diverge from two centres.

Radiant I at $44° + 59°$, $2\frac{1}{2}°$ preceding B Camelopardi;
" II at $42{\cdot}5° + 54°$, nearly midway between γ and η Persei.

The former point agrees with Mr. Denning's observations† at $44° + 58°{\cdot}5$, $43° + 59°$, and $43° + 58°$) of the position of the Perseïd radiant-point in August 1874–6–7; and it is in close proximity (3° N. of *k* Persei at $54° + 56°$) with the radiant-point of the Perseïd shower in August, 1863, recog-

* The same shower has also been variously recorded, between the dates of July 20th and August 13th, by Heis and Neumayer, Schmidt, and Weiss (six positions), and is G. 109 in Mr. Greg's General List of Meteor Showers, 1875–6. The shower of meteors with long courses, diverging from a radiant near Fomathaut, seen by Professor A. S. Herschel on the 28th of July, 1865 (see these Reports, vol. for 1865, pp. 104, 123), appears, on reprojecting their recorded paths, to have been, without doubt, one of the regular appearances of this shower, four of whose meteor paths, traced backwards, intersecting each other accidentally with exactness near that southern star, gave a false impression of the radiant's position (at $338° - 28°$), 15° south of the true one in declination.

† See these Reports, vols. for 1876, page 151, and 1877, p. 158 (foot-notes), and vol. for 1877, p. 173. The same places are also given (Nos. 18, 16, and 65) in Mr. Denning's three shower-lists, in the 'Monthly Notices' of the Royal Astronomical Society (vol. xxxvi., p. 284; xxxvii., p. 108; and xxxviii., p. 305) of 1871–75, 1876, and 1877.

nised by Schiaparelli as agreeing almost exactly with the radiant-point of the Perseïd comet, 1862 III, at about 43° + 57°·5. The second radiant-point agrees with Heis' position, A_{11} of the centre of the Perseids at 45° + 52°, and also with the radiant-point of a more recent comet, 1870 I, on August 12th, at 43°·5 + 53°. It may perhaps be that these two comets represent two meteor streams which are in simultaneous activity in the Perseus shower, and in his remarks on this accordance (here quoted from his description of the Perseïds of the present year in 'The Observatory,' vol. ii. p. 165) Mr. Denning notices an equally remarkable coincidence, which he regards as offering even more conclusive evidence of the latter comet's connection with the Perseus shower, that the rich and long-enduring shower of the Perseïds, seen with prolonged intensity on the nights of the 10th–11th* (and with many fine meteors on the 12th and 13th) of August, 1871, happened a year after that comet's appearance, in the same manner that the extraordinary Perseïd shower of August 10th, 1863, occurred in the year following that in which the comet 1862 III made its appearance. The two instances of near concurrence between a comet and a meteor-shower resemble each other very closely, and there appears, indeed, to be no reasonable possibility of rejecting the conclusion that the conspicuous return of the August Perseids in the year 1871 was not a simple maximum of their ordinary stream, but the result of a passing contribution to its swarm of shooting-stars by the passage very near the earth's path of a second meteor-comet, attended by a second zone or multitude of Perseïds of August 10th–12th, moving in a slightly different companion orbit from that of the first or annually-recurring shower, and of the meteor-comet corresponding to the Perseïds of August 10th. A strict examination of the August radiant-point, hereafter, will be most desirable to decide the question if, like the major stream of Perseïds between k Persei and B Camelopardi (at 44° + 58°), the fellow-stream at γ Persei (43° + 53°) is an annually recurring one, and forms, like the ordinary Perseïds of August 10th, a closed belt or ring of meteors circulating in a continuous stream, or travels in a single, or in detached clusters, round the sun.

Mr. Corder's view of the Perseïds, at Writtle ('The Observatory,' vol. ii. p. 160), was, in point of numbers and in the position of the radiant-point, very similar to Mr. Denning's. In four hours, between 11^h 30^m and 3^h 30^m, 113 meteors (of which ninety-seven were Perseïds) were seen. The mean horary number (twenty-eight of all meteors, and twenty-four of Perseïds) was much exceeded during the hour between 2^h 15^m and 3^h 15^m a.m., when forty-four meteors were observed. Of the ninety-seven Perseïds seen, sixty left streaks, and twenty were coloured. One which appeared at 2^h 28^m a.m. must have been much brighter than Venus, in its flash at bursting, as it cast a sensible glare upon a lamplit page. Its streak remained visible in the sky, from 352° + 48° to 341° + 40°, long

* In the map of the meteor-tracks of this shower, seen near the radiant-point on August 10th and 11th, which is figured at p. 91 of the volume for 1872 of these Reports, 36 of the 135 meteor-paths there drawn (or 27 per cent.) diverge, as Mr. Denning has found, pretty exactly from a radiant-point at 42° + 54°. The remainder of the tracks proceed principally from a radiant region in rather higher declination, belonging perhaps properly to the true Perseid comet, while the former point denotes the fellow-comet, 1870 I. Of the meteor-paths on the nights of August 12th and 13th few were recorded, but of such tracks of them as were noted it would certainly be a very important utilisation to endeavour to define the exact radiant-point in Perseus which they exhibit by a similar projection.

enough to record its track exactly. The recorded paths of forty or fifty Perseïds laid down in a map gave the radiant-point of the shower most accordantly at 43° + 56°. Another means of ascertaining it was also adopted by prolonging the short tracks of several meteors seen and mapped near the radiant-point at about 1^h a.m. backwards, with the resulting position, 45° + 57°; and a perfectly stationary meteor was seen at 47° + 58°. The precision of the meteors' radiation from the general radiant-point was surprising, much more so than on August 10th, 1877, when the radiant region was diffuse with a general centre at 47° + 62°. The apparent shifting of the radiant-point, then observed, to a more accurate one at 58° + 56° on August 11th, could not be verified in the present year, as on that date the sky was quite overcast. Both at Writtle and at Bristol many meteors were seen on the nights of August 7th and 8th, including several Perseïds and some Cassiopeiads. From the Perseïds seen on the 7th Mr. Denning found a position of the radiant-point at 42° + 57°, and Mr. Corder one at 43° + 55°.

Although not remarkably intense, the radiation of the August Perseids, in the year 1878, yet seems from all these descriptions to have been unusually exact.

Catalogues of meteor-showers, and *Directions to Observers of Luminous Meteors.*—The example first set by Heis of observing the general centres of radiation of shooting-stars on ordinary nights of the year has borne abundant fruit during a long period of more than thirty years; but at the same time never more rapidly, perhaps, than during the last two or three.

Towards the end of last year was published, as the conclusion of his own labours in this field of observation and reduction, a full and perfect compilation, recently projected and finally completed by the late Professor Heis, of the results of his original or otherwise recorded observations, and of the calculations and determinations founded upon them, accompanied by comparisons with the work of other professional observers with whom he continued to be in constant communication on this and other subjects of his long-continued investigations until the last days of his life. The work was issued, a few months after his decease, to the astronomical public, as one of the ordinary publications* of the Royal Observatory of Münster, under the joint editorship of his daughters and the supervision of one of the great astronomer's thoroughly accomplished pupils. Of this work the Committee received, in pursuance of a previous arrangement with Professor Heis, a communication of fifty copies from the Münster University librarians, by the directions of the late Professor Heis' daughters; and with the assistance of their recommendations the greater part of these copies were distributed, towards the close of last year, to a number of British and foreign observers and leading observatories, selected as having been his most active co-operators in the observation of meteors, and in the collection and discussion of phenomena relating to the astronomical theory of shooting-stars.

The work comprises, in 180 quarto pages, here and there illustrated with woodcuts, the apparent paths and brief descriptions of about 13,000 shooting-stars observed under Professor Heis' own directions at Aix-la-Chapelle and Münster, and of about 3000 meteors seen elsewhere in Germany, and in other countries. Of this latter number the author's wide cor-

* Vol. ii., 1877:—(as was noticed in the last volume of these Reports, for 1877, p. 101.)

respondence enabled him to receive and to publish many accounts in the well-known astronomical journal begun and conducted by himself for a long course of years, the 'Wochenschrift für Astronomie,' and frequent references to this weekly journal occur in the meteor catalogue of the work. The narrative portion, forming the remainder of the volume, contains the results of calculations and reductions from the catalogue, lists of stationary meteors, of meteors with serpentine paths, and of dates of unusual frequency and scarcity of shooting-stars. The introduction of this part also discusses and explains the practical mode of observing and the methods of calculation used, by which, with very little change since their first adoption in the year 1833, the whole of the important results of the author's forty-three years' observations of meteors presented in the volume were obtained. Among the many meteors simultaneously recorded at two or more stations, the heights at first appearance of 246, and at disappearance of 273, are calculated; and the following table, translated into British statute miles from the corresponding table of the work, exhibits the numbers of these heights respectively which fall in the successive nine-mile intervals (nearly) of height above the earth's surface extending to

Height above the earth (miles).	18	27	37	46	55	64	74	83	92	101	110	119	129	138	147	156
Number of initial heights.	0	3	12	19	26	35	38	23	24	19	16	7	4	6	5	1
Number of end heights.	3	21	44	55	64	31	23	15	4	4	2	4	1	1	0	0

The most frequent height of commencement is between sixty-five and seventy miles, and the most frequent height of disappearance of the meteors appears by this table to be about forty-five miles above the earth's surface.

A useful table might be constructed from the nights of the year on which shooting-stars were noted as unusually abundant, to guide observers in watching for their extraordinary displays, but the extent and fulness of this record in the original work forbids a partial summary to be presented here of its contents, until they can be more thoroughly examined and arranged to serve conveniently and usefully for such a purpose. At the end of this appendix a careful analysis is given by Mr. Greg of the new and greatly enlarged list of Heis' radiant-points, obtained by the author's special method of reduction from the meteor-paths described in the catalogue, with which the work concludes. A very large increase of their number above that of the last earlier list (of eighty-four showers; see the volume of these reports for 1873, p. 403) published by the late Professor Heis, has principally been made in the last half of the year; and the co-ordinates of position of a few of the old showers (which retain their appellations, while numerals and special symbols denote the new ones) have at the same time been changed and rectified by the discussions of the newer observations. The Committee avails itself of this opportunity to present, with the analysis of the new radiant-list of Heis, that published in 1871, in the German translation of his work on shooting-stars, by Professor Schiaparelli, the meteor-showers of which are frequently quoted, and identified with certain meteor-tracks, in Heis' final reductions. Of this list (with the exception of an

abridgment for the whole year, and of a preliminary list for the first half-year in full, see the volumes of these reports for 1870, p. 98, and 1871, p. 46) no entire abstract for useful reference has hitherto appeared in these reports. A series of instructions to observers for recording meteors and meteorites, drawn up at the request of the Committee by Dr. W. Flight and Professor Herschel, to furnish both regular and occasional observers of meteors of every kind with suitable directions as to the proper means and methods of recording them, and for preserving useful particulars of their various phenomena, is added to these lists with a view of facilitating their consultation and perusal by those who may fortunately be observers of star-showers, or who may be desirous of tracing the directions of large meteors from some of the many active radiant-points with which the sky is found to be more or less thickly strewn at all the ordinary hours and seasons of the year.

Important lists, both of his own observations of such showers throughout the year 1877, and of similar showers for the whole year found by searches and projections of the meteor-tracks in the Italian Meteor Association catalogue of shooting-stars for the year 1872, were published during the past year by Mr. Denning.* The first of these is a continuation of his two earlier lists of twenty-seven, and of fifty-two meteor-showers for the four years ending in March, 1876, and for April–December, 1876, published in the 'Monthly Notices of the Royal Astronomical Society,' vol. xxxvi. pp. 283–285, and vol. xxxvii. pp. 105–115†; and it includes new positions and notes of the appearances of 162 meteor-showers deduced from the paths of 1,929 shooting-stars registered by himself, chiefly in the last half of the year 1877. Descriptions of the majority of the most conspicuous of these showers, showing especially the dates of their maximum abundance, are given in the accompanying list of 'Remarkable meteor-showers in the years 1877–78.' The second list contains the positions of 315 radiant-points deduced by systematic projections of about 4,000 of the 7,500 meteor-paths (omitting about 3,500 tracks observed on August 3rd–14th) recorded by the Italian Meteor Association in the year 1872. This first catalogue of the Italian Association's observations falls naturally into thirteen periods separated by void intervals owing to the brightness of full moonlight; and grouping two of these into one (February–March, and November–December) in two cases where the showers were little distinguishable from each other, Mr. Denning de-

* 'Monthly Notices' of the Royal Astronomical Society, vol. xxxviii. p. 303 (for the declinations of the last three showers on the page, + 1, 1, 2, *read* + 15, 19, 22); and *Ibid.*, p. 315; March, 1878.

† The Table of fifty-two radiant-points observed and engrossed together in a list by Mr. Denning, at p. 176 of the volume of these Reports for 1877, is a partial combination of the two above lists extending as far as October, 1876. It was communicated (in the form in which it is there presented) to the 'Astronomische Nachrichten,' towards the end of the year 1876, as was noted at p. 162 of the last volume of these Reports. But in the above English publications of Mr. Denning's earlier lists, the first (of April 1876, twenty-seven radiants) extends to March, 1876; and the second (of fifty-two radiants, January, 1877), from April to December, 1876. They are referred to in the accompanying 'List of Remarkable Star-showers,' as D., or D. (71–6), and D. (76), while the combined list of last year's Report will be designated (if again referred to) DN, or DN (76); and that of 162 showers, observed in the year 1877 (published, as above notified, by Mr. Denning in the present year,) is denoted by D (77); Mr. Denning's Table of Reductions of the Italian Catalogue of 1872 (published at the same time) by DS.

duced for each of the resulting eleven periods a series of showers or radiant-points, of which the following were the various numbers:—

Number of Group	Duration of Group	Number of Showers	Number of Shower-meteors
I	January 1–15	30	313
II	February 1–March 12	24	381
III	March 31–April 12	37	542
IV	May 3–15	22	269
V	May 26–June 13	31	356
VI	June 26–July 11	36	459
VII	July 15–August 2	27	264
VIII	August 6–12 (a.m.)	25	413
IX	August 24–September 14	36	455
X	October 29–November 13	24	255
XI	November 25–December 31	23	436
	Totals, January–December	315	4,143

The showers are frequently recurrent in two, or even more successive periods; and of the whole number nearly 200 are probably distinct meteor-systems, with well determined radiant-points, most of the dates and positions of their centres agreeing well with those of formerly-known showers, occurring in earlier catalogues; but many of them also are new, and a few are apparently rich systems, agreeing in some cases with cometary dates and radiant-points.

Of these two shower-catalogues, showing where they corroborate each other and confirm older well-established positions of general radiant-points of shooting-stars, Mr. Greg has prepared a Table (Table V. p. 358) continuing and completing the analysis (Tables I.—IV., in the last volume of these Reports, pp. 180–187) for the first half of the year, which he made last year of Mr. Denning's observations, and Italian meteor-shower reductions. The limits of that analysis are now extended, by this additional table, so as to afford a complete comparative list of the newly found radiant-positions traced by Mr. Denning, for all the different months of the year.

As a result of his arrangement at O'Gyalla for collecting observations of shooting-stars in Hungary (some MS. lists of which at its commencement, see the note in these Reports, vol. for 1877, p. 165, the Committee received formerly), Herr N. von Konkoly presented to the Committee, at the end of last year, two volumes of meteor observations, containing observed paths and notes of the appearances of 1191 and 1367 meteors respectively, recorded during the years 1871–73, and 1874–76. To assist and promote accurate registration of meteor-tracks, and the collection of such accounts among astronomers of his own and other countries, Herr von Konkoly has had drawn and lithographed (by Carl Schräder, of his observatory at O'Gyalla) two planispheres, or central projections of the sphere on two planes touching it, one at the pole, and the other at the equator of the heavens. No stars are entered on the plates, which contain the meridians and parallel circles only, for each degree, but a catalogue of them from the north pole to the 30th degree of south declination, and full directions for their insertion on the

blank plates, and a long and valuable explanation of the various means of mapping, and recording and reducing to their radiant-points (and even to their real paths and distances) the tracks of shooting-stars, and of noting the special appearances of fireballs, when any such are seen, accompanies the plates in a lithographed pamphlet, also drawn up by Carl Schräder. The spherical radius of the maps is 25 cm. or 9·85 in., a little less than the radius, 12 in., to which the six similarly ruled plates of the Useful Knowledge Society's Atlas, (drawn by the late Sir John Lubbock) are constructed. But instead of being only 50 cm. square, so as simply to enclose the sphere in a circumscribing cube (like the maps just mentioned), the plates are 59 cm. square, and reach at the sides to 50°, instead of to 45°, and at the corners to 59°, instead of to 55° from the centre of the map. The cubical projection of the O'Gyalla maps extends accordingly upon each face, to about 5° beyond the edges of the cube; and meteor-tracks prolonged to the edge of either of its six maps, admit, therefore, of being easily transcribed in part (and these prolonged with a straight ruler) upon the next adjoining map. This kind of projection of the sphere lends itself, therefore, very conveniently to determining radiant-points of shooting-stars, at whatever hour and day of the year, and in whatever geographical latitude of the globe, a sufficient number of their apparent paths may have been observed.

Besides the large Münster catalogue of Professor Heis, and Herr von Konkoly's Hungarian catalogue of meteor-tracks, two long lists of shooting-stars, by Professor Dorna, of Turin, recorded at the Royal Italian Observatory of that city, in November, 1867, and August, 1869, (presented to the Committee some years ago by the author) have, in addition, furnished Mr. Denning with some new materials, of which he has availed himself, to deduce additional lists of meteor-showers, partly for the special dates of the major annual star-showers of April, August, and November, and partly in general for the last half of the year. This last list, containing ninety-two radiant-points will, it is hoped, shortly be published. Of the former lists, one at least, that of circum-Lyra radiant-points of April 19th–23rd, was recently described in a brief paper, on 'the April Lyrids [in 1878] and contemporary Meteor-showers,' in the 'Monthly Notices of the Royal Astronomical Society,' by Mr. Denning.* Among many thousands of paths (chiefly found for this date in Dr. Weiss's Austrian Meteor-catalogue, 1867–74) Mr. Denning selected about 300, as radiating from centres in Cygnus, Draco, Lyra, Vulpecula, etc., and deduced eighteen radiant-positions from them, three or four, at least, of which may be regarded as exact and well determined, although (from want of proximity, doubtless, to their maximum dates) they are yet very inconsiderable showers. Accompanying the principal shower in Lyra are two very slender ones, near π and β Lyræ; but in the adjoining constellations the principal contemporaneous showers are, first, a well-known shower at o Draconis (the *Draconids*, G. 64, 22↓s); secondly, a new, exact and certain shower between δ and η Cygni (25↓s), with several other showers in Cygnus, near ψ, π, ν, λ, ϵ, and ζ Cygni, to which one, pretty well confirmed from other sources, may be added near s Vulpeculæ. Thirdly, systems near α and β Cephei (of fifteen or sixteen meteors each) and a weak shower in the southern part of Lacerta. And lastly, a well-defined shower in Anser (20↓s) with two

* Vol. xxxviii. p. 396; May, 1878.

weak showers near it, in Sagitta, and one in Taurus Poniatovii. Both the Anser-Sagitta showers and the one near Taurus Poniatovii, seem to have been noticed previously by Mr. Denning, (Nos. 30, 34, 1877) on April 16th–19th, 1877, and by Captain Tupman (T. 35, 34) on May 2nd, 1870, and they present some resemblances to the hypothetical shower-radiants of the comets 1853 II, and 1844 II, which passed at the nodal dates, May 1st, and April 21st, slightly within the earth's orbit at their descending nodes. Some other accordances of the same kind presented by these new April showers are pointed out in the accompanying Table.

Comet-Node	Date and Position of Radiant-point, and No of Meteors	Description of Radiant-point.
1844 II ☋, (⊕ distance − 0 08)	April 21........... 288°·5 + 5°	Near δ Aquilæ.
	May 2, 1870 ...... 285 +12	T 34. Near ζ, 18 Aquilæ.
	April 16–19, 1877 286 + 5 (12 ↓s)	D (77), 34. Near δ Aquilæ.
	April 19–23 ...... 275 +11 (7 ↓s)	DW &c. Taurus Poniatovii.
1857 II ☋, (⊕ distance − 0 07)	May 1 .... 296·5 + 13·5	Near γ Aquilæ, β Sagittæ.
	May 2, 1870 ...... 298 + 5	T 35. Near β Aquilæ.
	April 16–19, 1877 303 +13 (8 ↓s)	D (77), 30. Near ρ-Aquilæ.
	April 19–23 { 287 +22 (20 ↓s)	DW &c. Near σ (Bode) and 5 Vulpeculæ.
	April 19–23 { 292 +14 (7 ↓s)	DW &c. Near β Sagittæ, γ Aquilæ.
	April 19–23 { 302 +18 (6 ↓s)	DW &c. Near γ Sagittæ, ρ Aquilæ.
1790 III ☋, (⊕ distance − 0·06) [And 1763 ☋, Mar. 18, + 0·02, 312·5 + 21·5]	April 24........... 319 +19	Near e (Bode) Pegasi.
	May and June ... 310 +24	G (76), 74. Near r (Bode) Vulpeculæ.
	April 19–23 ...... 312 +22 (13 ↓s)	DW &c. Near s (Bode) Vulpeculæ.
1784 II ☋, (⊕ distance + 0·06)	April 26........... 334·5 + 33	Near π Pegasi.
	April 19–23 { 321 +31 (8 ↓s)	DW &c. Near μ, ζ Cygni.
	April 19–23 { 332 +42 (5 ↓s)	DW &c. Near m (Bode) Lacertæ.

The rough approximations of a few of the slenderest circum-Lyrid radiants to some hypothetical comet-showers, which this Table shows, ar e much too loose to allow any certain inferences of connection to be drawn from them, but the resemblances in the cases of the second and third of these accordances are perhaps sufficiently well marked to merit attention, and to give occasions for renewed investigation.

A list of sixty-seven cases (omitting the four indubitable comet-showers of the Lyrids, Perseïds, Leonids and Andromedes) of similar loose agreements between observed meteor-showers, and hypothetical comet ones, by Professor Herschel, appeared during the past year in the pages (p. 369–395) of the 'Monthly Notices,' immediately preceding those of the paper by Mr. Denning which has just been quoted. Of these accordances it is enough to say, that while single instances occur where the correspondence is tolerably close, they are in all such cases unsupported, at present, by corroborative determinations, and that they have among the numberless similar questionable instances of comet-likeness, and even

of questionable determinations of the meteor-showers themselves, rather the appearance of being accidental coincidences than clear proofs of real resemblance or of positive identity. The cases of the accordances (noticed above, pp. 326 and 335) between the comet of 1870 I ☋, and the August Perseïd shower in 1871, and of the comet, 1825 II, ☋ (— 0·115, Oct. 7th, 134° + 77°) with a briefly enduring meteor-shower, noted by Mr. Denning on the nights of October 3rd and 4th, 1877, at 130° + 79°, are perhaps exceptions. Mr. Denning wrote that he never noted a shower better than this rich one during the two nights that its activity was at its maximum, and that in place and date of its appearance, its agreement with those of the hypothetical comet-shower was quite unexpected, and is practically perfect. This shower is unnoticed in the accordance (No. 49), where the observation properly belongs; but when duly inserted and added there to the previous tokens of resemblance to the comet which showers observed by Heis and Denning are shown to present, it would be the best marked, and most certainly verified accordance of any of the nearly positive and determinate ordinary cometic correspondences which are recorded in the list. Mr. Denning also communicates the following meteor-shower positions as having escaped notice in some of the other accordances of the list which are here briefly denoted by their reference Nos., the comet's node, and the omitted meteor-showers.

39, 1864 II ☋	Aug. 3–12........	31° + 28°	Schm.
	„ 6–12........	32 + 20	(11 ↓ s) DS, viii., 13.
	Aug.—Sept.......	30 + 20	Corder, 1877.
44, 961 ☊ & ☋...	Sept.—Oct. ...	39 − 9	(20 ↓s) DZ.
54, 1739 ☋	Sept.15—Oct. ...	154 + 41	(9↓s) D (77), 90.
	Sept. 8—Oct. ...	155 + 41	(13 ↓s) DZ.
	Oct. 29—Nov. 13	160 + 40	(8 ↓s) DS, x., 18.
55, 1757 ☋......	Oct. 12–13	23 − 13	(7 ↓s)DZ.

The following accordances are new:—

42 b 1790 I ☋...	Sept. 16	108 + 37·5	(W.) + 0·05.
	Sept. 16–30	108 + 38	(10 ↓s) Heis (77). M_{11}.
	Sept.—Oct.......	111 + 37	(20 ↓s) D &c.
	Oct. 2–19.........	108 + 38	(19 ↓s) D (77) 108; suspected also in September.
56a. 1849 I ☋...	Oct 29.........	185 + 61	(W) + 0·02, or
		165 + 75	+ 0·02 (?)
	Oct. 2–18.........	167 + 75	(5 ↓s), (78). 92; a feeble shower.
	Nov. 1–7	164 + 74	(5 ↓s) DZ).
	Nov. 4—Dec. 19	160 + 71	GH (74), KG } = G (76), 176.
	Nov. 1–15	180 + 65	Schm. }

The lists of cometary radiant-points ('N' in the northern, and 'S' in the southern hemispheres) at pp. 232, 234 of the volume for 1875 of these Reports, it may also be noticed here contain a few important errors, which require the following corrections:—N. 59; *for* Sept. 2, 57°+2° *read* Aug. 22, 57°+21°.—N. 45; *add* and ☊; *for* (13 to) 27 *read* (26 to) 27.—N. 43*a* (end of the list); *for* June 28, 42°+14° *read* March 17, 34°+15°.—S. 7 (Clausen's); *for* 14°·5−0°·5 *read* 353°−8°.—S. 11*a* (end of the list); *for* March 6 *read* Dec. 9.

Much stress was laid by Mr. Denning and Mr. Greg in two papers

read to the Royal Astronomical Society* in January and April last, on the long-observed duration of some meteor-showers, with stationary radiant-points. That the centres of divergence of ordinary shooting-stars in general occupy almost fixed positions in the heavens for several days, or even weeks, together, is indeed conceded by nearly all the observers who have recorded and discussed their radiant-points. But a much more strange and extraordinary peculiarity of these showers was believed to have been noticed by Mr. Denning, that after a first appearance, or period of prevalence of an ordinary meteor-shower, followed by a lull, or interval of entire cessation of its action, a radiant-point will again make its appearance with renewed activity, forming apparently, a repetition of the original meteor-shower in everything except its date, at an interval of about three months after its first display. Examples of such recurrences were traced by Mr. Denning, between August–September and October–December, between October–December and February–April, and between April–May and July–August meteor-showers. The end arrived at hitherto, by continued observations, has been to multiply ceaselessly the number of new radiant-points, and to discover sub-showers, as tributary streams in systems which had formerly been held to be thoroughly well isolated and defined. The multiplicity of radiant-points which thus accumulate from year to year, are chiefly congregated near the meteor-epochs of August, November, and April, when it is not unreasonable to expect, from the numbers which have been recorded, and from the attention naturally concentrated upon well-known regions of the sky, that frequent repetitions of radiant-points, at intervals of about three months should, in general, be traceable in different seasons of the year. The slenderly supported evidences of connection between cometary and meteor-shower radiant-points, in a multitude of cases where they very nearly approach each other, is an indication how much chance may have to do with frequent occurrences of such an apparent resemblance, even between contemporaneous radiant-points, and in a list of cometary radiant-points, not unfrequent instances may be selected of recurrences of identical positions, with periods of one or two, and sometimes of three or more, months intervening between them. The theoretical grounds on which the hypothesis of trimestral meteor-showers is shown to be untenable, were clearly urged, in some apposite remarks appended to Mr. Denning's paper, by Captain Tupman; and, indeed, no deep acquaintance with Physical Astronomy is required, to show that, even if it should be indubitably established by further observations and researches, no such hypothesis could be derived directly, in the present state of the science of astronomical perturbations, from any supposed primitive relation of the orbits or assumed remote or recent origin of scattered and diffuse, or of still compact and undisintegrated meteor-showers.

Of the circum-Perseïd showers of August 6th–12th, Mr. Denning also prepared a list, by projecting numerous meteors of the periodic dates in the catalogues of the Italian observers (1872), Heis (1852–72), and von Konkoly (1871–76). The positions and numbers of meteors belonging to each radiant, as collectively determined by one or more of those three

* Monthly Notices of the Royal Astronomical Society, vol. xxxviii., pp. 111–116, and 351.

meteor-records (denoted by the letters S, H, K, in the list) are repre-sented in the following table.

Circum-Perseïd Meteor-showers (W. F. Denning), August 6th–12th.

Position of Radiant α δ	No. of Meteors	Sources of Observ.	Approximate place of the Radiant by the stars	Coroborations from other sources; and Remarks
$68° + 64°$	55	S H K.	Near *c* (Bode) Camelopardi	D (77) 77; rich (10 ↓s) Aug. 10–12, 1877, at 70° + 65°; 4 ↓s, only in the Hungarian Catalogue.
62 + 38	46	S H.	Near ϵ *f* Persei	
97 + 71	62	S H.	„ *p q* Camelopardi	
52 + 75	51	S H K.	„ *m o* (Bode) Custodis	4 ↓s only in Hungarian Catalogue.
60 + 49	49	S H K.	„ λ Persei	
78 + 56	42	S H K.	5° p. δ Aurigæ	(Stationary ↓ July 20, 1878, at 76° + 54°); Weiss, Aug. 11, 1869, 77° + 54°.
74 + 46	26	S H K.	Near α Aurigæ	
48 + 47	24	S H K.	„ α Persei	
76 + 33	21	S.	....	
92 + 56	18	S.	3° nf δ Aurigæ	
135 + 76	16	H.	8° n. of σ Ursæ Majoris	
52 + 20	11	S.	4° sp. η Tauri	
44 + 33	16	S K.	Between Medusa and Triangulum.	
87 + 34	8	S.	Near θ Aurigæ	
141 + 71	8	S.	4° nf. σ Ursæ Majoris	

Fine meteors from some of these showers often accompany the Perseïd display, and will probably be recognised as diverging from certain of these centres in future observations of the shower.

Mr. Denning has also completed some reductions of various observers' records of circum-Leonid and circum-Geminid showers, of which the following table gives the principal results. All the available meteor-catalogues were employed in the reductions.

Mr. Denning draws attention to the long durations shown in this table, not only of radiant-points in Leo and Leo Minor, quite distinct (though less apparently so by Schmidt's determination in October) from the November *Leonids*; but also of three showers in Cancer, near ι, β-ζ, and especially near δ Cancri, with very fixed radiant-points, as illustrating a very commonly occurring peculiarity in such general radiant-points of shooting-stars, when deduced independently from a variety of sources. Such a long-continued shower Mr. Denning and Mr. Corder noted in great activity from July to September, near κ Persei (at 47° + 45°) distinct from, though very liable to be confused with the Perseïds. Close to this shower itself, a series of radiants indeed appears to continue in prolonged activity from July to December.

With regard to the Taurids of November and December, Mr. Denning notices that a radiant deduced for December, from the Italian observations, (D S. XI, 13, at 64° + 15°, 7↓s), principally marked on December 6th, confirms a subradiant of the showers of Taurids I (60° + 20°), at 70° + 15° (5↓s), which he noticed (D'77, 158) between November 25th and

December 13th, 1877, and considers that closer investigation at the end of November may succeed in distinguishing this new shower from those of Taurids I and Taurids II (at 80° + 23°).

Circum-Leonid (and Geminid) Meteor-showers of November 1st–15th, (and December 9th–13th). W. F. Denning.

Position of Radiant α δ	No. of Meteors	Radiants' approx. place by the stars	Corroborative Meteor-showers; and Remarks. [The number of mapped meteors of a shower is noted in parentheses, thus (9), immediately after the position of its radiant-point.]
142 +29 143 +28	31 (Dec. 9–12)	Near ϵ Leonis " "	Oct. 15–18, 140° + 28° (9) D (77) 120 October, 140 +23 Schm. Dec. 12, 136 +30 Masters. Jan. 1–15, 140 +30 (6) DS. I, 19 A long continued shower: meteors with streaks like the Leonids.
133 +48	26	Near κ Ursæ Majoris	Oct. 2–19, 130 +47 (11) D (77) 110; active, max. Oct. 15–16; seen also in September.
149 +38 150 +43	23 (Dec. 9–12)	In Leo Minor, near μ Ursæ Majoris	Oct. 2–18, 153° + 42° (4) D (77) 90. Dec. 9, 1868, 150 +43 DZ. Jan. 1–15, 150 +43 (7) D S. I, 20 Exact radiant close to μ Ursæ Majoris.
130 +31	15	ι Cancri ...	Oct. 28—Nov. 13, 133 +31 (10) Nov. 25—Dec. 13, 131 +32 (6) D (77) 139 Radiant endures a long time.
122 +14 120 +15	13 (Dec. 9–12)	At ½ (β, ζ) Cancri " "	Oct. 15–18, 120 +15 (9) D (77) 119 Jan. 1–15, 120 +15 (6) DS. I, 25 Distinct from 127° +17° in Nov., No. 118; long-enduring shower of short swift meteors.
132 +20 133 +12	17 Dec. 9–12	Near δ Cancri " "	Oct 11, 128 +20 T. 88, suspected. Oct. 15–19, 133 +21 (18) Oct. 28—Nov. 13, 127 +17 (12) D (77) 118 Oct. 29—Nov. 13, 135 +21 (12) DS X. 17 Dec. 21—Jan. 5, 130 +20 D W. Jan. 1–15 130 +24 (7) DS. I, 7 Feb.—March 12 129 +22 (19) DS. II, 7 Feb. 13–16 132 +23 DZ. A long-enduring shower of meteors with long paths; very swift in October and November.

An elaborate paper of reductions of the observed paths of 2,450 shooting-stars, of the first 20 days of November, by Herr Louis Gruber, of the Imperial Observatory of Vienna, was communicated last year to the Academy of Sciences of Buda-Pesth, and it also forms an appendix in the January number of the 'Memorie degli Spettroscopisti Italiani.' From the miscellaneous collection of these meteor-tracks, Herr Gruber extracts the following places and durations of twelve November radiant-points, of which he also indicates in some measure the characters of importance. As the paper is of some length, and the conclusions drawn from it are of considerable interest, the Committee is obliged in the present notice to confine itself to this indication of its value, and to an acknowledgment for its obliging communication to the author.

Of discussions of the proportions of meteor-magnitudes, by Mr. E. F. Sawyer of Boston, and by other observers; of papers of great interest

on the history and distribution of meteoric matter in planetary and terrestrial rocks, and in the sea and atmosphere, for which it has been indebted during the past year to the authors, Dr. von Tschermak, Mons. Daubrée, Messrs. S. Meunier and G. Tissandier, and Mr. John Murray, of Edinburgh, the Committee is also obliged by the length of this Report, while recording the value of their contributions to the subjects of which they treat, to omit a short review until a more favourable opportunity permits it to give full and appropriate descriptions of them in another year.*

Positions and Durations of meteor-showers in the early part of November, by L. Gruber, 1877.

No. of Shower	Date of Duration Nov.	Date of Max. Nov.	Position of Radiant α δ	Per cent. No. of meteors, or importance of the shower
I.	1–18	13·0	$148^\circ + 19^\circ$	Leonids, 26 p. c. of all.
(I.)		12	140·5 + 21 149·5 + 12	Nov. 12, 1871. A double radiant-point of the Leonids observed by L. Gruber.
II.	1–18	14·5 6	57 + 30·5 55 + 19	Taurids, 22 p. c. „ Do. 52 ↓s, Tupman.
III.	4–14	13·5	111 + 59·5	About 10 p. c. of all.
IV.	1–18	13·5	62 + 53	„ „ „
V.	9–12	11	70 + 19·5	Remaining radiants about 33 p. c. of all.
VI.	2–14	10	103 + 3	
VII.	1–18	18	135 + 52	
VIII.	9–13	13	100 + 41	
IX.	3–12	6	125 + 5	
X.	7–10	8	10 + 39	
XI.	11–13	12	316 + 71	No radiant, Tachini 356° + 87°·5, found near the North Pole.
XII.	....	3	53 − 14 40 − 25	A position included on this line

III. Account of Aerolites. By Dr. Flight.

Found 1858–9.—*Staunton, Augusta Co., Virginia.*†

In 1871 Mallet described three masses of meteoric iron which had been found near Staunton; another has now been brought to light, and examined. It was found by a negro in 1858 or 1859, who brought it to

* With the exception of the notes on meteor-magnitudes and colours ('The Observatory,' vol. i., p. 399, and ii., pp. 20, 23, 97), and of the discovery of spherules of magnetic oxide of iron in various ancient sandstones, and in different specimens of sea mud, by Messrs. S. Meunier and G. Tissandier, in vol. lxxx. of the 'Comptes Rendus,' a short account of all the above recent papers on meteoritic subjects is given (in the 'Monthly Notices of the Royal Astronomical Society,' vol. xxxviii., p. 219–221) in a sketch of the 'progress of meteoric astronomy during the year 1877,' communicated in the Council's Annual Report for the past year, in February last, 1878, to the Royal Astronomical Society. A Paper by Professor D. Kirkwood, read before the American Philosophical Society, on March 1st, 1878, should also be noticed here (see 'The Observatory,' vol. ii., p. 118), showing the probable independence of the stonefall occurrences of the 13–14th of November, and the system of Leonid meteor-showers of the same well-known meteoric date.

† J. W. Mallet. *Amer. Jour. Science*, 1878, xv. 337.

Staunton, and endeavoured to sell it. He failed to do so, and threw it away behind a blacksmith's shop, where it lay several years until it was used with other loose material to build a stone fence. By reason of its irregular shape and great weight it soon fell out of the fence, and was next used by a dentist as an anvil, on which to hammer metal plates, and for such base purposes as the cracking of nuts; then it was again built into a wall round the curbing of a cistern. In 1877 it was removed to Rochester, N.Y., and a fragment of it came into Mallet's possession. It weighs 152 pounds, is 45·7 cm. in length, and 29·2 cm. in breadth, and in shape somewhat resembles that of a shoulder of mutton. A sketch of the mass is given in Mallet's paper. The specific gravity of the iron is 7·688, and the metal when etched, exhibits the Wiedmannstättian figures "clearly and beautifully." The composition of the iron was found to be:

Iron	91·139
Nickel	7·559
Cobalt	0.608
Copper	0·021
Tin	trace
Phosphorus	0·068
Sulphur	0·018
Chlorine	trace
Carbon	0·142
Silicium (reckoned as silicic acid)	0.108
	99·963

There can be no doubt that the four specimens found in the same neighbourhood represent different portions of the same meteoric fall.

1861, *June 28th (June 16th, O.S.)* 7 *a.m. Grosnaja (Grosnja), Banks of the Terek, Caucasus. Russia.**

Sixteen years ago Abich, who was at the time in Tiflis, sent to Gustav Rose, in Berlin, a short description of a large fall of meteorites at Grosnaja on the morning of the above day. The greater number appear to have fallen into the river Terek; one fell in the great square in the interior of the (? Staniza) barrack, entered the ground to the depth of 1¾ feet; it pursued an oblique course through the air, and was distinctly warm when dug out. The meteorite had the form of a huge hailstone, and was covered with a black crust.

Abich, who has taken up his residence in Vienna, placed the stone in the hands of Professors Tschermak and Ludwig for examination, and the results of their investigations, together with a detailed report of the circumstances attending its descent, have been incorporated in the paper by Professor Tschermak, referred to in the note.

It is stated in the report drawn up by General-Major Kundukof, military commandant of the Tschetschensk district, that on the night of the 15th–16th June (O.S.), a barely dark one, there was neither thunder, wind, nor rain. On Friday, the 16th, the morning was clear and bright; light rain-clouds, which however brought no rain, hung on the western horizon over the station Mekenskoi, the inhabitants of which were startled at about seven o'clock by a deafening sound, which continued a long space of time. A non-commissioned officer of the Mosdok regiment, who was walking from the Navursky to the Mikenskoi barracks (? Staniza),

* G. Tschermak, 'Mineralogische und Petrographische Mittheilungen,' 1878, 153.

AN ANALYSIS OF PROF. DR. ED. HEIS' (1877) CATALOGUE OF METEOR SHOWERS. By R. P. Greg.

Heis Nos.	Radiant Position R.A.	Radiant Position Dec.	Epoch	No. of Meteors	Observations	B.A. Cat. 1876 (Greg) No.	B.A. Cat. 1876 (Greg) R.A.	B.A. Cat. 1876 (Greg) Dec.
N 4	252°	+79°	Jan. 1—Feb. 27	8		1		
N 1. 2.	322	+85	Jan. 1–20	8		1	116°	+87°
N 3	0	+90	Feb. 4–15	10		1		
K 1. 12Z^{19}.	198	+55	Jan. 2–13	7		4	201	+54
A 1.	31	+55	Jan. 2–29	7	? = same	7	22	+56
3 Z^{10}	10	+61	Jan. 10–19	5				
M 1	115	+51	Jan. 1–13	6		2	131	+48
M 2	101	+51	Jan. 10–29	6		32 ?	105	+62
F 1. 10.	296	+53	Dec. 8—Jan. 25	16		A	'*Cygnids*' of Denning at 295	+53
St. 1	227	+55	Jan. 1–30	3	(not '*Quadrantids*')	17	225	+4
St. 2 *a*.	117	+42	Jan. 2–30	11	(not = St. 2 *b*.			
14 Z $^{11\ 12}$	45	+44	Jan. 2–26	8	New			
M 3	172	+55	Feb. 4–27	3		21	180	+76
A 4	80	+40	Feb. 16–28	4		24	77	+44
S 1	175	+20	Feb. 1–10	4	'*Virginids*'	28	175	+14
St. 3	131	+36	Feb. 17–24	3		31 ?	133	+26
A 5	55	+52	March 1–15	5		38	50	+48
G H 11 *a*.	28	+67	March 5–25	4		189	36	+67
M 16	150	+44	March 18—April 3	7		45	147	+47
R 1	162	+24	March 2–28	6		26	158	+29
St. 2 *b*.	180	+5	March 4—April 2	9	(not St. 2 *a*.)	28 *a*	181	+6
V. S 3	180	+20	March 21—April 18	8	Same as last ?	28	175	+14
G H 13	224	+38	March 13—April 29	17		48	223	+42
S 4	190	+23	April 4–22	11	? = S 5	54	190	+24
A 7	83	+44	April 2–18	5	New ? ?			
S 5	206	+13	April 13—May 11	24	? = S 4	62 ?	199	+9
A 8	64	+63	April 18–19	6	New ? ?			
C 1	277	+34	April 18–29	12	'*Lyrids*'	51	272	+35
F 2	261	+44	April 18–28	8		47	263	+50
G H 12*a*. Z 14	202	+53	April 8–27	7		55	204	+56
G H 14. S 6.	191	+7	April 18—May 18	12		62	199	+9
M 7	179	+49	April 5–22	12		46	180	+56

M 8	162	+59	April 17–30	13		56 ?	162	+48
N 7	60	+89	April 1–28	9	= same	60 ?	228	+81
N 8	320	+81	April 14–28	8		65	289	+81
N 9	315	+81	May 5—June 15	7		65	289	+81
48 Z²	230	+26	April 20–24	4	'*Coronids*'	67	235	+23
M 9	175	+61	May 5—June 23	10	New ?			
Q 2 *a.*	328	+46	May 21—June 22	5		71	235	+45
Q 2 *b.*	212	+12	June 4–27	7	New			
72 Z¹⁴	280	+35	June 17–28	3		72	280	+34
F 3	260	+54	June 15—July 27	10	? = F 4	102 ?	248	+62
F 4	286	+58	June 11—July 25	6	'*Draconids*' II	78	282	+60
F 5	275	+48	June 14—July 25	19	? = F 3	78 ?	282	+60
Q 3. *a.b.c.d.*	260	+9	July 10—August 30	35		87	270	+7
G H 30. N 11. 12. 13	10	+88	July 7—August 15	222	(Averaged)	93	302	+87
Cr. 6	355	+81	August 1–10	87		93		
A 10	24	+50	July 22–25	14	? New			
B 4	324	+51	July 22—August 28	502	'*Lacertids*'	112	335	+52
	to 328	+51				193 ?		
F 3	269	+36	July 16–25	15		113 ?	281	+38 Aug., Sept.
F 6. 122 Z	270	+36	July 16—August 11	155	? New			
St. 19	294	+44	August 3–30	192	? New			
F 7. 8	286	+48	July 8—August 11	260				
	to 295	+54						
F 8. *b.*	250	+58	July 26–31	11		102	218	+62
G H 25	15	+70	July 14–29	16	'*Cassiopeids*' I	83	12	+64
A 9	25	+63						
G H 26	338	+13	July 19–31	49	'*Pegasids*' II	97	338	+17
Y 1. Ξ 1. St. 24	to 337½	+9½			? contd. at T 1			
G H 29	315	+31	July 19–29	22	*Cygnids* I	101	315	+30
G H 29. B 3	309½	+50	July 7–29	21	*Cygnids* II	81	309	+48
Q 2. *b.*	241	+11	July 23–27	7	= same	88	249	+19
G H 32	216	+21	July 26–27	5				
Ξ 5	319	−9	July 19—August 31	25		198	323	−8
G H 28	294	+13	July 26–31	24	'*Aquilids*'	107	301	+8
Ξ 2. 3. 4	305	+7	July 14—August 31	132				
6. 7. 9. T 1	310	+17	August 11	11				
H. 2	217	+63	July 28—August 2	18		81	214	+55
H 250 H 16	344	+21	July 28—August 6	61	(353° + 24° average)	111 ?	359	+13
	356	+27						

ANALYSIS OF PROF. DR. ED. HEIS' (1877) CATALOGUE OF METEOR SHOWERS—*continued.*

Heis' Nos.	Radiant Position. R.A.	Radiant Position. Dec.	Epoch.	No. of Meteors	Observations	B.A. Cat. 1876 (Grey) No.	B.A. Cat. 1876 (Grey) R.A.	B.A. Cat. 1876 (Grey) Dec.
II 252. 262	65°	+71°	July 28—August 4 ...	30	(Averaged)	...	New.	
St. 10	336	−5	July 21—August 2 ...	27	'*Aquariads*'	109	337	—6
St. 11	38	+30	July 22—August 2 ...	28	New..............................			
St. 7	8	+20	July 20—August 6 ...	34	New?	111 ?	⅓ (Nos. 103. 106. 111) ?	
St. 8. Z 123	344	+42	July 22—August 1 ...	107	'*Honorids*'......................	95	340	+41
118 Z[28]	174	+55	July 22–29	9	....	99	170	+54
119 Z[28]	336	+30	July 24–31	21	'*Pegasids*' I.	96	338	+26
116. 120. 126. 109. 130. 133. Z	307	+38	July 26—August 4 ...	26	....	81	309	+18
121. 131. 136 Z.	265	+54	July 25—August 6 ...	20	New ?			
122 Z[29]	278	+36	July 26–29	11	....	113	281	+38 Aug., Sept.
85 Z[5]	222	+60	July 11–14	3	....	84	214	+55
117 Z[28]	298	+36	July 19–31	11	New?			
A 12. 13. 11	42	+62	Aug. 13—Sept. 30... ..	93	(39° + 63° to 48° + 62°)	116	38	+57
St. 9	37½	+48	July 16—Aug. 2	37				
A 11	15	+50	Aug. 1–24	425	'*Perseids*'	108	14	+56
St. 12. 14. 21	41	+49	Aug. 1–27	211				
II 248	38	+56	July 30—Aug. 2	15				
B 5	292	+70	Aug. 3–19	226	....	78	282	+60 July, Aug.
W 1	190	+13	Aug. 13–22..............	9	New?			
Z 135. N 14	295	+79	Aug 11—Sept. 13	81	....	93 ?	302	+87
Ξ 8	313	+19	Aug. 12–19..............	22	....	107		
Z 136	254	+37	Aug. 1–6..................	5	....	110	257	+30
Z 131	261	+60	Aug. 1–6..................	6	....	121	264	+64
St. 15. 20 Cr. 18	54	+73	Aug. 1–29	189	(Averaged)......................	192	50	+75 Sept.
St. 13	215	+42	Aug. 1–21	63	New..............................			
St. 17	27	+21	Aug. 4–28	116	....	121 ?	26	+35
St. 18	25	+58	Aug. 4–21	390	....	116 *a*	25	+59
St. 22	80	+43	Aug. 4–21	12	New?			
St. 23	314	−8	Aug. 12–22..............	13	....	198 ?	328	−12
St. 25	320	+63	Aug. 12—Sept. 28.....	112	New ?	77 ? 125 ?	317 345	+62 +65 June, July
Cr. 4	19	+52	Aug. 1—6	74	'*Cassiopeiads*' II.	98 ?	7	+50
Cr. 5. St. 26	11½	+31½	Aug. 1—Sept. 30	140	....	103	7	+33

Cr. 7	297 +37	Aug. 1–21	91		81 ?	309 +48
Cr. 8. 14	8½ +66	Aug. 8–28	201	'*Cassiopeiads*' I	83	12 +64
					131 ?	60 +61 (Sept.)
Cr. 9	74 +63	Aug. 8–23	159	? New	122 ?	95 +62 (Aug., Sept.)
Cr. 10	86 +51	Aug. 9–21	52	New		
Cr. 11	273 +56	Aug. 9–31	124		78	282 +60, July and Aug.
Cr. 13	61 +39	Aug. 11–26	17		111	67 +47
Cr. 16	354 +27	Aug. 11–19	15	New ? ?	111 ?	⅓ (Nos. 96. 111. 103) ?
Cr. 17	275 +69	Aug. 13–31	17		78 ?	
Cr. 19	181 +61	Aug. 11–22	10		99	170 +54
G. 2	55 +37	Sept. 1–30	10	'*Musoids*' ?	129 ?	46 +35
G H 33	285 +41	Sept. 8–16	5		113	281 +38
J 2 (I 2)	2 +56	Sept. 1—Oct. 21	27	= same	98	7 +50
J 3 (I 3)	1 +45	Oct. 1—Nov. 15	54			
M 11	155 +56	Sept. 25–30	10	New ?		
N. 15. 16	100 +81	Sept. 11–30	35		128	105 +86
St. 27	45 +10	Sept. 1–13	32		123	46 +35
St. 28	223 +27	Sept. 25–29	5	Doubtful		
St. 29	292 +68	Sept. 10–26	8		130	302 +62
B 5 *a*	290 +72	Sept. 22—Oct. 31	16	(In part B 5)		
T 1 (Y 1)	312 +9	Sept. 1–30	19	'*Pegasids*' II	97	338 +17
T 2	1 +14	Sept. 16–31	47	(? = Cr. 16)	111	359 +13
U 2	328 +35	Sept. 16—Oct. 26	32	New ?	96 ?	⅓ (Nos. 96. 101. 95) ?
ψ 2	50 −1	Sept. 21–29	3	'*Eridanids*'	138	40 −6
152 Z 23	28 +35	Sept. 19—Oct. 15	10		100	26 +35
153 Z 28	83 +51	Sept. 21—Oct. 11	9	'*Aurigids*' ?	136	84 +48
A 16. 163 Z 28	74½ +44	Oct. 17–31	39			
B 7	286 +56	Sept. 1–28	28	New ?		
B 8	311 +65	Sept. 16–30	19		129	302 +62
(Z 28) A 15	47 +56	Oct. 3—Nov. 14	86	? A 14 contd.	168	46 +55
A 15 *a*	59 +53	Nov. 15–27	10	(? = St. 32)	?	New ?
B 9	315 +59	Oct. 3—Nov. 13	50	same ? ?	193 ?	319 +53 (Sept.)
B 9 *a*	315 +49	Nov. 15—Dec. 13	15		151	312 +48
B 10	338 +56	Oct. 17—Dec. 23	90	? = E	144	342 +46
P 1	24 +12	Oct. 17—Nov. 23	147	'*Andromedes*'	172	25 +43
P 2	46 +1	Nov. 1–14	27		138	40 −6
T 3	2 +19	Oct. 17—Dec. 10	90	? New, ? = T 1	111 ?	259 +13 (Sept.)
E (B 10 ?)	355 +54	Oct. 22—Nov. 14	31	? = B 10	144	342 +56
G 1	24 +27	Oct. 17—Nov. 23	45		154 *a*	21 +22

ANALYSIS OF PROF. DR. ED. HEIS' 1877 CATALOGUE OF METEOR SHOWERS—*continued.*

Heis' Nos.	Radiant Position. R.A.	Radiant Position. Dec.	Epoch	No. of Meteors	Observations	B.A. Cat. 1876 (Greg) No.	B.A. Cat. 1876 (Greg) R.A.	B.A. Cat. 1876 (Greg) Dec.
G 2. 3	83	+28	Oct. 17—Nov. 15	47		135	74	+27
G 4. 9	102	+31	Oct. 17—Nov. 14	30	'*Gemellids*'	142	105	+27
G 12	21	+55	Oct. 18—Nov. 14	7	? = A 19	172 *a*	21	+60
F 9	238	+51	Oct. 17—Nov. 14	19	New			
M 12. St. 35	121	+34	Oct. 21—Dec. 8	49		170	121	+42
M 13	155	+65	Nov. 1–13	36		194	159	+56
N 17. 18	215	+81½	Oct. 17–31	41	? = N 19	143	105	+86
G 15	250	+87						
R 3. G 12	45	+33	Oct. 2—Nov. 11	51	'*Muscids*'	129	46	+35
	37	+38						
T. 3	1	+19½	Oct. 1—Dec. 23	95	*Max.*: 19 – 25 Oct.	207	2	+25 (Dec. ? ?)
St. 31	272	+31	Oct. 2—Nov. 14	37	New ?	113 ?	281	+38 (Aug. Sept.)
St. 32	55	+45	Oct. 2—Nov. 23	67	? = A 15 *a*	159	61	+42
Σ 2	347	—13	Oct. 3–15	3		105	9	–9
154 Z 5	240	+63	Oct. 3–16	5		140	217	+68
A 17. 19	15	+62	Nov. 2—Dec. 21	111		172 *a*	21	+60
	to 22	+55						
A 18	59	+53	Nov. 15–24	6	Doubtful			
St. 34. G 6	58	+12	Nov. 9—Dec. 23	53	'*Taurids*'	156	60	+19
D	282	+53	Nov. 15—Dec. 9	8		166	286	+57
L	148	+24	Nov. 12–13	20	'*Leonids*'	171	149	+23
N. 19. 20. 21	110	+87	Nov. 6—Dec. 24	65	(20° + 87° to 135° + 87°)	177	201	+85
T 4	10	+52	Nov. 11–28	22		173	14	+57
T 5	10	+5	Nov. 11–14	15	(not 10° + 52°)		New ?	
H 1	74	+45	Dec. 2–13	38	(? = 163 Z^{28}	201	83	+45
P 3	24	+10	Dec. 18–22	3		150	28	+28 (Dec.)
G 5	95	+33	Dec. 8–11	14	'*Geminids*'	178 ?	105	+32
M 14. 180 Z^9	115	+55	Dec. 7–23	59		182	108	+63
Cr. 22	66	+34	Dec. 3–11	30		159	61	+42
Cr. 23	118	+26	Dec. 7–13	13	New ?	?	[illegible] (Nos. 178. 175. 187) ?	
179 Z^9.	100	+59	Dec. 8–10	5		182	108	+63
181 Z^9.	136	+40	Dec. 8–11	8		175	135	+40
Total Radiants, 156 Sub-radiants, 44					Total meteors, 6,588			

A List of Radiant-points of Shooting Stars, from the observations of J. Zezioli, at Bergamo, during the years 1867, 1868, 1869. By J. V. Schiaparelli. (Extracted from Prof. Schiaparelli's Work, translated into German by Dr. G. von Boguslawski, 'Entwurf Beiner Astronomischen Theorie der Sternschnuppen,' Stettin, 1871, p. 84–101). The Remarks condensed from Notes in an Appendix of the original Catalogue:—

Ref. No.	Date of Shower			Position of Radiant α	δ	Remarks
				°	°	
1		Jan.	6	199	+58	
2		„	6	175	+48	
3		„	10	10	+57	
4		„	11	47	+40	
5	(1869)	„	11–12	183	+28	Observed on both days 184° + 28°, 182° + 29°: ? = MG (G. & H.); and = ☄ 1792 II (Weiss); accordance doubtful.
7		„	17	120	+57	
8	(1869)	„	18	232	+36	Radiant accurate, from 21 meteor-tracks.
9		„	19	198	+28	
10		„	19	218	+37	
11		„	19	244	+64	
12		„	19	200	+59	
13		„	21	205	+49	
14		„	21	218	+29	
15		„	21	210	+20	
16		„	24	195	+56	
17		„	27	132	+67	
18		„	27	205	+47	
19	(1868)	„	28	67	+25	AG (G. & H.) 68° + 20°, December 20—February 6.—Scattered radiation, the radiant being 151° from apex of earth's way.
20	(1868)	„	28	236	+25	January 29, a.m.; 134 meteors counted, 61 mapped, in $1^h\ 45^m$; two observers. Radiant diffuse, but no other traceable; 24 tracks with this place.
21		„	29	198	+54	
22		„	30	225	−34	
23		„	31	134	+40	= $M_{1,\ 2}$ (G. & H.), 128° + 40°, Max. January 25–31. (' = ☄ 1680, Weiss.)
24		„	31	221	+28	
25		Feb.	1	215	+30	
26		„	3	153	+21	
27		„	5	212	+22	
28		„	6	130	+49	
29		„	6	240	+62	
30		„	6	187	+31	
31		„	6	183	+56	= M_3 (Heis), 171° + 56°, February 1–14.
32		„	13	133	+26	
33		„	13	232	+30	
34		„	14	105	+62	
35		„	14	205	+51	
36		„	14	263	+68	
37		„	15	133	+55	
38		„	15	214	+53	
39		„	16	74	+48	= $A_{3,\ 4}$ (G. & H.), 73° + 40°, February 9–17; and = $A_{\ 4}$ (Heis), 76° + 40°, February 15–28.

A LIST OF RADIANT-POINTS OF SHOOTING-STARS, &C.—*continued.*

Ref. No.	Date of Shower	Position of Radiant α	δ	Remarks
		°	°	
40	(1868) Feb. 17	237	+46	
41	„ 19	240	+56	
42	Mar. 17	186	+56	
43	„ 20	144	+48	= M_6 (Heis), 150° + 47°, March 16–31. Radiant region elongated; its centre being 131° from apex of earth's way.
44	„ 27	238	+24	
45	„ 30	215	+55	
46	April 1	261	+47	
47	„ 2	212	+51	
48	„ 2	230	+26	
49	(1868–9) „ 2–3	259	+38	Observed both days, 258°+36°, 260°+40°. Apparently distinct from QH_1 (G. & H.), 268° + 25°, March–April; max. April 13, 1864.
50	„ 9	255	+36	
51	„ 9	246	+16	
52	„ 10	163	+47	= M_8 (Heis), 160°+49°, April 20 period. Not visible between April 10 and 14 (No. 56); ? if connected.
and 56	„ 14	168	+47	
53	„ 11	193	+20	Radiant region diffuse; may perhaps be grouped with S_4, S_5 (Heis).
54	„ 13	231	−27	Agrees with ☄ 1847 I, except in perihelion distance: (compare No. 143).
55	„ 14	202	+56	
56 (52)	„ 14	168	+47	131° from apex of earth's way.
57	„ 14	263	+50	
58	„ 14	240	+55	
59	„ 14	212	+55	
60	„ 23	250	+40	
61	„ 25	142	+53	Radiant well defined. Observed in zenith; 143° from apex of earth's way.
62	„ 25	256	+75	
63	„ 25	260	+24	= ☄ 1748 II (?; observations of comet and meteor-shower not very exact.)
64	„ 29	182	+27	131° from apex of earth's way.
65 (70)	(1867–8) „ 30	237	+35	And 1868, May 1, at same place = Q_2 (G. & H.), 235° + 30°, April 23—June 4; and Q_1 (Heis), 232° + 27°, May 1–31?
66	May 2	204	+35	
67	„ 16	238	+36	
68	„ 18	263	+38	
69	„ 22	300	+44	
70 (65)	„ 22	232	+25	Forms perhaps with 65 and Q_1 (Heis) a common group. Agrees better than 65 with Q_1 (Heis).
71	„ 24	240	+44	
72	„ 24	207	+47	
73	„ 24	302	+30	
74	„ 25	280	+54	
75	„ 25	277	+39	
76	„ 26	237	+59	
77	June 2	227	+30	
78	„ 9	207	+37	

A LIST OF RADIANT-POINTS OF SHOOTING-STARS, &c.—*continued.*

Ref. No.	Date of Shower	Position of Radiant α	δ	Remarks
79	(1867–8) June 14	280°	+35°	Compares well with W (G. & H.), 280° + 29°, May 6—June 20; and Schmidt, June, 284° + 38°.
80	„ 19	300	+41	
81	„ 28	269	+44	
82	„ 28	302	+27	
83	„ 30	240	+19	Good agreements with Q_2 (Heis), 242° + 12°, June 1–30; Schmidt, 235° + 23°, June; and Q_1 (G. & H.), 245° + 21°, April 23—June 30.
84	July 4	3	+68	
85	„ 5	222	+60	
86	„ 5	304	+45	
87	„ 5	247	+29	
88	„ 6	289	+34	
89	„ 8	288	+64	
90	„ 9	280	+40	
91	„ 9	247	+60	
92	„ 11	300	+49	
93	„ 11	8	+44	
94	„ 13	338	+65	
95	„ 14	270	+51	
96	„ 17–18	244	+59	
97	„ 18	272	+44	
98	„ 18	332	+35	
99	„ 18	317	+47	
100	„ 18	342	+23	Schmidt, 345° + 25°, July 5–25.
101	„ 18	324	+69	B_4 (Heis) July 15–31, 320° + 70°.
102	„ 18	315	+61	
103	„ 19	338	+43	
104	„ 19	332	+23	
105	„ 19	355	+60	Plane of orbit perpendicular to the ecliptic.
106	„ 19	334	+45	
107	„ 21	330	+64	
108	„ 21	240	+76	
109	„ 21	313	+40	['Cygnids' BG (G. & H.), July 4—August 22 (max. July 30), 315° + 31°; Schmidt, July 5–30, 317° + 32°; B 4 (G. & H.), and Nos. 99, 112, 116, 120, and 126 in this list are perhaps connected with it.
110	„ 21	11	+38	
111	„ 21	0	+55	
112	„ 23	308	+42	
113	„ 23	336	+30	
114	„ 24	309	+61	
115	„ 24	330	+88	
116	„ 25	303	+41	
117	„ 28	298	+36	
118	„ 28	174	+55	Schmidt, end of July, 165° + 62°; V (G. & H.), July 29—September 6, 172° + 60°. Good agreement of orbit with comet 1737 II (Weiss, Schmidt, Schiaparelli).
119	„ 28	336	+30	
120	„ 28	305	+35	

A LIST OF RADIANT-POINTS OF SHOOTING-STARS, &c.—*continued.*

Ref. No.	Date of Shower	Position of Radiant α	δ	Remarks
		°	°	
121	(1867–8) July 29	266	+52	
122	„ 29	278	+36	
123	„ 30	345	+40	
124	(1867–69) „ 30–31	275	+37	Schmidt, end of July, 277° + 40°; and ? B_5 (G. & H.), August 2—September 25, 285° + 44°; observed three times by Zezioli.
125	„ 30	32	+35	
126	„ 31	308	+49	
127	„ 31	318	+59	
128	„ 31	287	+61	
129	„ 31	3	+49	
130	Aug. 1	10	+56	
131	„ 3	264	+40	
132	„ 3	35	+44	
133	„ 4	304	+44	
134	„ 4	342	+29	Schmidt, August 1–15, 338° + 30°. Agreement with T_1 (G. & H.), June 29—August 24, 338 + 13, '*Pegasids*' doubtful. Perihel. in S. lat. 90°.
135	„ 5	315	+80	
136	„ 6	254	+37	
137	„ 7	42	+48	
138	„ 7	12	+56	
139	(1868–9) „ 10	43	+57	(*Perseids*); agreement of orbit with that of comet 1862 III almost precise. Many allied radiant-points contiguous to it; see Nos. 132, 137, 142, 144.
140	(1869) „ 10	47	+18	Accurate; 9 meteors in $1^h\ 15^m$. 2° distant from earth's *apex*. Radiant of comet 1862 II (August 19), 47° + 13° (Weiss).
141	„ 11	24	+58	
142	„ 11	47	+43	
143	„ 11	—	+90	N_{13} (G. & H., and Heis), August, near N. Pole. But for its small perihelion distance, tail fragments of the great comet 1853 III may have produced this shower, or No. 135, (very doubtful; Weiss and Schiaparelli.)
144	„ 12	47	+55	
145	„ 28	340	+65	
146	Sept. 5	321	+60	Schmidt, September, 309 + 67; B_8 (Heis), September 16–30, 311° + 65°; and ? E (G. & H.), August and September, 335° + 52°.
147	„ 6	60	+32	Slightly observed. R_1 (Heis), September 1–15, 53° + 35°.
148	„ 7	60	+70	
149	„ 12	60	+60	
150	„ 18	51	+39	R_2 (Heis), September 16–30, 46° + 37°.
151	„ 20	317	+47	
152	„ 23	28	+35	
153	„ 28	83	+54	A. S. Herschel, September 27, 1864, 85° + 50°; $F_{1,2}$ (G. & H.), September 17—November 24, 83° + 50°.
154	Oct. 5	240	+63	

A LIST OF RADIANT-POINTS OF SHOOTING-STARS, &c.—*continued.*

Ref. No.	Date of Shower			Position of Radiant α	δ	Remarks
				°	°	
155	(1868)	Oct.	12	53	+27	Position very accurate, to 1° or 2°. Fine shower of 22 meteors, 6 per hour. Motion in orbit nearly towards the sun. R_3 (Heis), Oct. 1–15, 45° + 32°, and R_3 (G. & H.), are near.
156		„	13	80	+19	Schmidt, October 10–27, 79° + 13°.
157	(1868)	„	21	75	+25	So also Tacchini, 1867, October 21. And Schmidt, October 10–27, 71° + 31°.
158		„	21	81	+26	
159		„	21	130	+48	Compare LG (G. & H.), October 3–20, 143° + 42°. ?
160	(1868)	„	21	96	+13	'*Orionids.*' O (G. & H.), October 17 November 13 ?, 90° + 15°. Radiant frequently observed; Schmidt, A. Herschel, 1863–68; and [or ? the next shower] by Herrick, October 20–27, 1839
161	(1868)	„	23	111	+29	Very accurate on October 21, 22, 24, 25; max. October 23, a.m. A fine, enduring shower; 13° from earth's 'apex.'
162		„	24	77	+45	A_{16} (Heis), October 16–31, 72° + 44°.
163		„	28	110	+70	
164		Nov.	9	61	+42	
165		„	10	70	+20	RG (G. & H.), October 25—November 21, 64° + 18°. R_4 (Heis), November period, 55° + 16° (? ?).
166		„	10	87	+47	= F_1 (G. & H.)? Schmidt, November 10–14, 82° + 45°.
167		„	10	138	+37	
168		„	12	6	+34	
169		„	12	115	+37	
170		„	13	352	+41	
171		„	13	40	+60	
172		„	17	120	+40	
173		„	19	142	+30	
174		„	23	100	+30	Perhaps connected with G (G. & H.), November 26—December 30, 100° + 33°. *max.* December 11–13.
175		„	26	107	+33	
176	(1867)	„	30	17	+48	*Andromedes.* Radiant of 7 meteors out of 9 in 2^h; certainly derived from Biela's comet. A_{19} (Heis) December 1–15, 21° + 54°.
177		„	30	145	+29	
178		Dec.	9	149	+45	
179		„	9	100	+59	
180		„	9	109	+60	
181		„	9	135	+37	Schmidt, December, 130° + 30°; and Stillman Masters, 1866, December 12, 136 + 29·5.
182		„	9	154	+26	
183		„	12	180	+53	
184		„	21	117	+67	
185		„	22	182	+40	
186		„	23	177	+31	
187		„	23	157	+64	
188		„	27	207	+47	
189		„	27	137	+45	

TABLE V.*

Denning, 1877, *continued*, England			No. of Meteors	Denning's 1872 Italian Reductions			No. of Meteors	Corresponding Observers	Mr. Greg's Catalogue B.A. 1876			Observations
R.A.	Dec.	Epoch		R.A.	Dec.	Epoch		R.A. Dec.	R.A.	Dec.	Cat. No.	
° 310	° +42	July 16—Aug. 16, 1876	?	° *	°	*		341° +42° Heis, July 22—Aug. 4.	° 310	° +41	95	'*Honorids.*'
344	+46	June 26—July 11	13	330	+42	July 15—Aug. 2	6	337° +47° (S.Z.)	,,		95	Do.
350	+37	July 6—Aug. 16	11	347	+36	Aug. 6..............	4	340° +43° Tup., Aug.......	,,		95	Do.
349	+53	July 6—Aug. 16	11	351	+53	July 15—Aug. 2	11	352° +53° Schmt., Aug. 4–11, and Sept.	,,		95 ?	Do. ? New.
335	+44	July 6—Aug. 16	21	342	+59	Aug. 24—Sept. 14	11	334° +48° Tup., Aug. 23	335	+52	112	'*Lacertids.*'
*		*	*	339	+46	Aug. 24—Sept. 14	24	331° +48° Corder, Sept., Oct.	,,		112	Do.
*		*	*	331	+50	Sept. 5–12	8	330° +55° Heis, Aug.	,,		112	Do.
7	+36	July 6—Sept. 16	40	10	+33	July 15—Sept. 14	45	*	7	+33	103	
280	+57	July 6–17 (June)	5	282	+61	July 15—Sept. 14	24	*	282	+60	78	'*Draconids*' II.
7	+53	July 6—Aug. 16	20	8	+54	July 15—Aug. 2	15	5° +50° Corder, Aug., Sept.	7	+50	98	'*Cassiopeiads*' II.
30	+36	Aug. 3—Oct. 20	26	23 to 34	+37 +35	July 15—Sept. 14	28	30° +40° Corder, 24 meteors, Aug., Sept.	26	+35	100	(SZ = 33° +34°)
36	+47	July 6–17	6	30	+47	July 15—Aug. 2	10	37° +40° Lorenzoni, Aug. 10	"		100 ?	New ? } = ?
24	+46	Aug. 3—Sept. 16	11	23	+45	Aug. 24—Sept. 14	20	23° +50° Heis, 1877, July 22–31.	,		100 ?	New ? } = ?
18	+63	Aug. 3–16	15	*		*	*	11° +60° Heis, Aug. 10	12	+64	83	'*Cassiopeiads*' I.
3	+22	July 6—Aug. 16	11	359	+20	Aug. 24—Sept. 14	29	*	359	+13	111	'*Pegasids*' III.
10	+28	Aug. 3–16	8	43	+23	Aug. 24—Sept. 14	28	50° +20° Corder, Aug., Sept.	50	+24	115 ?	47° +18° (Schmt., Aug.).
47	+28	Sept. 4—Oct. 20	8	45	+26	Oct. 14—Nov. ...	7	56° +33° Corder, Oct. ...	46	+35	129	'*Muscids.*'
60	+59	Aug. 3–16	5	64	+50	July 15—Sept. 14	23	58° +56° Corder, Aug. 11	67	+47	114	59° +56° (Sept. 7–15), Tupman.
61	+48	Aug. 7—Nov. 13	32	60	+47	Sept. 5–12	11	56° +47° Schmt., Aug.	67	+47	,,	
47	+45	July 6—Sept. 16	18	44	+43	Aug. 24—Sept. 14	7	45° +50° Corder, Sept.	(New)		*	45° +40°, Heis, Sept. 50° +48° (Schmt. Aug.)
70	+65	Aug. 3–12	10	64	+65	Aug. 24—Sept. 14	13	60° +68° Corder, Sept. 74° +63° (Heis, Aug.)	60 Sept.	+61	131 ,,	68° +65° (SZ. Sept.)
31	+18	July 18—Aug. 16	12	*		*	*	27° +21° (Heis, Aug.)...	*		*	New.

315 +50	June 26—Aug. 16	21	316 +48	July 15—Sept. 14	9	304° +48° Aug., Sept., Corder.	309 +48	81	'Cygnids' I.
*	*		311 +65	Aug. 24—Sept. 14	24	307° +65° Aug. 17, do.	302 +62	130	
333 +26	July 11—Aug. 12	11	335 +27	July 15—Sept. 14	12	331° +21° June, Sept. Corder.	338 +26	96	'Pegasids' I.
340 +12	June 26—Aug. 16	18	343 +9	Sept. 5–12 ………	11	332° +12° Aug., Sept. Corder.	338 +17	97	'Pegasids' II.
330 +10	Aug. 3—Aug. 16	12	331 +12	July 15—Sept. 14	15	330° +12° Tup., Aug. 23	"	"	"
330 +70	July 6—Aug. 16	12	338 +61	July 15—Aug. 2	6	350° +58° July 26–31, Heis	345 +65	125	Aug.—Sept.
291 +15	July 6—Aug. 16	15	285 +44 291 +41	July 15—Sept. 14 July 15—Aug. 2	14 10	293° +42° Aug. 10, G. 289° +47° Aug., Corder	281 +38	113	N.B. (should be 289° +45°)
340 −10	July 6—Aug. 16	16	349 −1	July 15—Aug. 2	6	336° −6° Heis ……………	337 −6	109	'Aquarids.'
317 −11	July 6–20 ………	13	320 −12	July 1–11 ………	*	330° −1° Corder, Aug. Sept.	328 −12	198 ?	New ?
281 −11	June 26—Aug. 12	8	*	*	*	Not in Heis ………………	285 −13	201	
298 −8	July 6–17 ………	5	294 −7	July 15—Aug. 2	6	291° −7° July, Aug. Schmidt.	299 −7	79	
315 +81	July 6—Aug. 16	12	300 +82	Aug. 24—Sept. 14	14	275° +83° Oct. …………	302 +87	93	July—Sept.
310 +77	Sept. 1—Oct. 20	17	68 +81	Aug. 24—Sept. 14	15	68° +87° Corder, Sept. 23			
258 +37	July 6–17 ………	8	256 +37	July 15—Aug. 2	11	*	257 +30	90 110	June—Aug.
313 +33	July 6–17 ………	*	*	*	*	307° +30° Corder, Sept.…	315 +30	101	(315° +31° Heis).
306 +6	Aug. 3–16 ………	4	302 +9	July 15—Sept. 14	13	306° +6° Aug., Corder …	301 +8	107	'Aquilids.'
311 +67	Aug 3—Sept. 16	10	315 +60	July 15—Aug. 2	10	304° +58° Sept., Corder	317 +62	77 ?	June—Aug.
*	*	*	*	*	*	351° −2° to 5° +8° Sept. Corder.	9 −9	105	July—Sept.
271 +8	July 6–17 ………	5	272 +1	July 15—Aug. 2	6	*	270 +7	87	
56 +52	Oct. 2–20 ………	4	51 +55	Aug. 21—Sept. 14	18	48° +60° Heis, Sept. 15–31—Dec. 11	46 +15 Oct.—Dec.	168 ?	New ?
			*	*	*	47° +47° Corder ……			
43 +58	Aug. 3–16 ………	285	*	*	*	*	44 +56	108	'Perseids.'
			96 +71	Aug. 6–12 ………	60	95° +71°, Heis, Denning	*	*	
*	*	*	287 +27	July 15—Aug. 2	10	298° +36° July 29, Heis	*	*	New.
*	*	*	234 +66	July 15—Sept. 14	16	240° +63° Oct., SZ.	Oct.	140 ?	New ?
*	*	*	260 +63	July 15—Aug. 2	5	*	261 +64	124	
*	*	*	320 +23	do.	11	Not in Heis ………………	*	*	New.
*	*	*	100 +71	Aug. 6–12 ………	38	Not in Heis ……… ………	*	*	New.
18 +54	Sept. 4—Oct. 20	13	17 +61	Aug. 24—Sept. 14	23	*	14 +57	173	Sept., Oct.

* See the last volume of these Reports, pp. 180–187, for the Comparative Lists, Tables I.–IV., preceding this one, for the first half of the year.

Denning, 1877, *continued*, England R.A.	Dec.	Epoch	No. of Meteors	Denning's 1872 Italian Reductions R.A.	Dec.	Epoch	No. of Meteors	Corresponding Observers R.A. Dec.	Mr. Greg's Catalogue B.A. 1876 R.A.	Dec.	Cat. No.	Observations
°	°			°	°				°	°		
*		*	*	71	+33	Aug. 6	5	Not in Heis	*		*	Doubtful.
60	+85	Sept. 4—Oct. 20	16	? [50	+85	Aug. 6	4]	*	105	+86	128	
20	+8	Sept. 4—Oct. 20	8	15	+8	Aug. 24—Sept. 11	15	8° +8° Schmidt	18	+1	106	'*Piscids.*'
*		*	*	*		*	*	{120° +76° Corder, Sept., 8 meteors.}	105	+86	128 ?	Doubtful.
*		*	*	78	+23	Aug. 24—Sept. 14	14	80° +30° Corder, Sept.	74	+27	135	
186	+71	Oct. 2–20	6	180	+75	Aug. 24—Sept. 14	14	Not in Heis	*		*	New.
90	+14	Sept. 4—Nov. 13..	72	88	+7	Oct. 29—Nov. 13.	6	93°+16°, Corder...........	89	+15	157	'*Orionids.*'
61	+36	Sept. 4–16	15	{67 / 72	+35 / +41}	Aug. 24—Sept. 14.	16	70°+32°, Schmidt	67	+47	114 ?	
100	+58	do.	10	100	+56	do.	10	Not in Heis	95	+62	122	
267	+20	do.	4	{270 / 280	+20 / +30}	do.	13	Do.	*		*	New.
*		*	*	240	+25	do.	6	317°+27°, Corder, Oct. ...	249	+19	88	
246	+49	Sept. 4—Oct. 20..	12	260	+50	do.	5	252°+53°, Schmidt	267	+47	102 ?	New ?
155	+41	Sept. 4—Oct. 20..	9	*		*	*	Not in Heis	*		*	New ?
148	+79	do.	33	*		*	*	*	*		*	New.
217	+78	do.	18	*		*	*	230°+79°, Heis..............	247	+68	140 ?	New.
87	+34	Sept. 4–16	10	*		*	*	80°+30°, Corder, Sept. ...	*		*	New ?
254	+65	Sept. 4—Oct. 20..	10	*		*	*	Not in Heis .... {	264 / 247	+64 / +68	124 ? / 140 ?	
53	+64	Sept. 4–16	6	*		*	*	48°+62°, Heis..............	60	+61	131	
103	+11	Sept. 4—Nov. 13..	33	*		*	*	110°+14°, Corder, Oct. ...	107	+7	153	
59	+9	Sept. 4–16	5	*		*	*	Not in Heis	65	+3	117*a*	
77	+17	Sept. 4—Nov. 13..	19	*		*	*	67°+11°, Corder, Oct. ...	78	+11	134	
48	+15	do.	11	*		*	*	47°+14°, Corder, Oct. ...	51	+14	117*b*	
40	+72	Sept. 4–16	6	*		*	*	Not in Heis	50	+75	192	
109	+38	Sept. 4—Oct. 20..	20 }	*		*	*	107°+24°, Corder, Oct. ...	105	+27	142	'*Gemellids.*'
114	+27	Sept. 4—Nov. 13..	25 }									
84	+55	do.	26	83	+52	Sept. 5–12	6 ?	75°+45°, Corder, Oct. ...	84	+48	136	'*Aurigids.*'
130	+47	Sept. 4—Nov. 13..	18	130	+45	Oct. 29—Nov. 13..	*	{134°+44° / 127°+56°} Corder, Oct.	136	+46	141	{? (No. 175 at 135°+40° for Nov.–Dec.).
103	+49	Oct. 2–20	37	*		*	*	Not in Heis	*		*	New.

*	*	*	*	*	*	127° + 56°, Corder, Oct. ...	*	*	Doubtful. Not in Heis.
*	*	*	*	*	*	27° + 5° do. ...	28 + 8	150	
*	*	*	*	*	*	20° + 25°, Corder, Sept. -Oct.	21 + 22	151*a*	
*	*	*	*	*	*	344° + 15° do. ...	347 + 14	191	
*	*	*	*	*	*	11° + 22° do. ...	2 + 25	207	
*	*	*	*	*	*	300° − 6° do. ...	*	*	Doubtful.
*	*	*	*	*	*	254° − 2°, 10° − 2°, 5° + 8° Corder, Sept.	9 − 9	105	
101 + 73	Oct. 2—Nov. 13...	23	100 + 71	Oct. 29—Nov. 13..	5	*	91 + 71	208	
138 + 58	Oct. 2-20	10	*	*	*	Not in Heis	*	*	New ?
225 + 52	do.	10	*	*	*	Not in Heis	*	*	New ?
120 + 15	do.	9	*	*	*	Not in Heis	*	*	New ?
77 + 31	Oct. 2—Nov. 13...	17	*	*	*	81° + 82°, Heis..............	74 + 27	135	78° + 28°, Corder.
131 + 19	do.	30	135 + 17	Oct. 29—Nov. 13.	17	*	129 + 26	147	
143 + 27	do.	14	*	*	*	*	145 + 18	149	(140° + 23°, Schmidt.)
43 + 59	do.	15	47 + 56	Oct. 29—Nov. 13.	4	*	46 + 55	168	
60 + 20	do.	16	62 + 20	do.	13	55° + 17°, Corder...........	60 + 20	156	'*Taurids.*'
61 + 48	do.	16	62 + 47	do.	10	*	61 + 42	159	(Nov. 9.)
290 + 70	Oct. 2-20	7	280 + 70	do.	5	290° + 72°, Heis..............	302 + 62	130	(302° + 62° ?)
121 + 0	do.	6	*	*	*	*	115 − 10	196 ?	
33 + 50	Oct. 2—Nov. 13...	8	*	*	*	40° + 50°, SZ., 44° + 46°, Corder	46 + 55	168	(33° + 50° ?)
8 + 35	do.	9	9 + 37	Oct. 29—Nov. 13.	6	*	*	*	New.
*	*	*	*	*	*	42° + 39°, 41° + 46° Corder.........	33 + 40	167	(Deuza).
*	*	*	*	*	*	68° − 13° do.	57 − 9	164	
80 + 21	Oct. 2—Nov. 13...	9	*	*	*	*	80 + 23	210	Nov. 22—Dec. 13.
*	*	*	154 + 36	November, 1868 ...	13	*			
*	*	*	160 + 40	Oct. 29—Nov. 13.	8	160° + 40°, Tupman	160 + 40	165	
*	*	*	189 + 57	do.	8	*	180 + 59	179	
55 + 48	Nov. 27	?	*	*	*	*	*	*	(? = 168) G.
*	*	*	104 + 53	Dec. 31—Jan. 15.	15	*	*	*	
145 + 7	Dec. 9.....	5	*	*	*	145 + 5, T. average, Jan. 4-11	150 − 1	181*a*	Doubtful.
111 + 23	December	?	*	*	*	104 + 37, R. P. Greg.........	105 + 32	178	? = '*Geminids.*'
*	*	*	110 + 70	January, 1868......	9	*	*	*	*
*	*	*	25 + 41	Feb. 13, 1868......	7	*	*	*	*

noticed that the sound appeared to come from the west, where the rain-clouds were, and describes it as resembling that produced when many cannon are fired simultaneously, followed by a deafening noise like that caused by battalion-firing. He observed the fall of one of the stones, which descended at a low angle, and it was accompanied by lateral bands of a bluish colour (welcher von Nebenstreifen von bläulicher Farbe begleitet war). It fell in the court-yard of a house about two paces distant from a summer-house, and thirty paces from the bank of the Terek. A soldier's wife, standing on the threshold of the house, drew back in the greatest alarm as the meteorite struck the ground two paces from her with all the violence of a bomb-shell, scattering the earth over the wall of the house. A soldier soon probed the hole with a ramrod, and found at a depth of rather more than a foot fragments of the stone weighing in all ten pounds. Many heard a second sound, as though the meteorite burst twice in its descent through the atmosphere, and the noise attending the fall was observed by persons eight versts distant on the other side of the Terek. A woman who was occupied in washing clothes, at a spot about 1050 feet distant from the point where the meteorite struck the ground, heard fragments, which had been detached by the explosion, fall into the river Terek. The water fizzed just as it would when brought in contact with a large quantity of heated iron.

The meteorite has a longish rounded form, and has lost the greater portion of its crust; in fact, the crust, together with a thin layer of the enclosed silicate, is very easily removed, and probably dropped off at the time of the fall. Its actual thickness is much greater than in the case of the stones which fell at Knyahinya, and about as thick as that of the Pultusk aërolites.

Professor Tschermak goes on to describe the Vandal treatment to which the stone was subjected before it reached his house for investigation. A cast of it had been taken for the Academy of Sciences of St. Petersburg, and it had subsequently been sawn in two. It appears, in the first place, to have been rubbed down with fat, not oil even, and, after the mould was taken, to have been soaked with potash lye to remove the unctuous layer; the carbonate of potash, which penetrated the porous stone with scarcely any crust to protect it, next began to effloresce, and the new danger to which it was exposed had to be compassed by drenching it with water. It was now ready to pass from the clumsy hands of the modeller to experience the yet more tender mercies of the lapidary, who, not to be outdone by his fellow-workman, it is to be conjectured, proceeded to close all the fissures and lines upon its surface with a black varnish. Long treatment with alcohol and protracted drying in a steam bath were the next operations which were made with a view to cleanse it.

A system of cracks and fissures, arranged like the branches of a tree, traverses the whole stone, and gives us the impression that they are the result of the blow which the meteorite received on its fall. The mass of the stone is brittle, the colour blackish grey with bright points. There are many enclosed mineral particles, some almost invisible, others 1 cm. across, the greater part having a diameter of less than 2 mm. The matrix is black and opaque even when viewed in a microscopic section, and many of the enclosed particles are opaque or only translucent in points. Most of them, however, are transparent, and the majority have a circular or rounded outline. A plate is appended to Tschermak's paper showing figures of the enclosed minerals. Five distinct ingredients

could be distinguished. The first is a clear greenish mineral, with incomplete cleavage along two directions perpendicular to each other, and identified as olivine. A second in round tough spherules, brownish in hue and not numerous, with a finely foliated or finely fibrous structure, was found to be bronzite. Enclosed particles are sometimes made up of these two minerals, sometimes, but not very frequently, of them together with a third silicate in long greenish prisms which have the appearance and angles of augite. The meteorite also contains some magnetic pyrites (troilite ?), a very little nickel-iron and perhaps a little carbon, to which the dark hue of the matrix is due.

Tschermak directs attention to two peculiarities observed in several chondritic meteorites, and noticeable in this one. The first is the occurrence of a crust over the surface of the bronzite spherules, possessing fibrous structure. This crust is thin, and is distinguished from the enclosed material by its paler colour; it has the same fibrous structure, doubly refractive power, and, in fact, is optically orientated like the enclosed silicate. It appears to be produced by some agent acting from without, perhaps heat in conjunction with a reducing gas. The agent has not caused fusion, but a slight modification of the texture of the surface. The second point which he has observed is the distribution in zones of the magnetic pyrites in many of the granular enclosed masses. When a microscopic section is examined by reflected light, it is found that many are apparently surrounded by a crust of the metallic sulphide, in others it occupies the centre of the mass in all cases apparently filling up interstices. It seems as if the sulphide had impregnated the rocky mass, and the absence of all magnetic pyrites in the very compact enclosed particles and the tough fibrous bronzite chondra, confirms this view. This impregnation Tschermak believes took place after the enclosed mineral particles attained their present form, and the only explanation which can be suggested is that this must have happened while the whole tufacious mass was strongly heated. According to this theory, the enclosed granules coming in contact with fused magnetic pyrites must have drawn it into the fine fissures and interstices, in some instances into the cavities of the granules themselves.

This argues the existence of two definite stages in the formation of these and similar chondritic structures. First, the production of the olivinous tuff by the splitting and attrition of the rock when the tougher particles are rolled and rubbed together till they have a roundish or spherular form; and secondly, a subsequent application of heat to the tuff, accompanied not unfrequently by the reducing action of gases and vapours.

The Grosnaja meteorite appears to consist of—

Silicic acid	33·78
Alumina	3·44
Iron protoxide	28·86
Lime	3·22
Magnesia	23·55
Potash	0·30
Soda	0·63
Carbon	0·68
Hydrogen	0·17
Magnetic pyrites	5·37
	100·00

Olivine appears to be the prevailing silicate in the meteorite; in addition to bronzite there appears to be a little augite and felspar, although their presence could not be recognised. We find, moreover, a small amount of a carbonaceous ingredient, to which, as well as to the magnetic pyrites, the blackish grey colour of the matrix is probably due.

A plate showing six sections of the mineral constituents of this meteorite accompanies Tschermak's paper.

Found 1872.—*Neuntmannsdorf, near Pirna, Saxony.**

This mass of meteoric iron was found in 1872, and a superficial examination of it by Lichtenberger was made in the following year ('Sitzungsber. der Isis,' Dresden, 1873, p. 4). It is a rounded block of malleable iron, weighing 25 pounds, and covered with a blackish-brown crust of oxide. Like the meteoric irons of Ovifak, Disko Island, Greenland, and many others, it contains chlorine, and in damp warm air rapidly oxidises and exfoliates. The metal has the grey colour of iron, does not exhibit the Wiedmann-stättian figures, and has a specific gravity of 6·21. Geinitz finds the composition of this iron to be—

Iron	93·04
Nickel	6·16
Phosphorus	0·22
	99·42

In the iron are many rounded, sometimes elongated, hollows filled with a yellowish-brown mineral having the specific gravity = 3·98. This on analysis was found to consist of—

Iron	63·82
Sulphur	37·36
	101·18

which showed it to be troilite (iron monosulphide), and to accord in composition with the sulphide found in the meteoric iron of Seeläsgen. One cavity was filled with what appeared to be the same mineral in a crystalline form. This is the first occasion where troilite has been met with otherwise than massive.

1875, *March 31st.*—*Zsadány, Temesvar Comitat, Banat.*†

We directed attention to the fall of this meteorite in the Report for the year 1875. Dr. Cohen, of Heidelberg, received some fragments of the stone from Dr. Babesin, and he has recently published a paper on the results of the physical and chemical examination of them.

The crust of the stone has a brownish black colour, and is $\frac{1}{5}$ to $\frac{1}{4}$ mm. in thickness; it has the appearance as though it had not been subjected to so intense a heat as that usually developed during the fall of a meteorite. The finely grained light grey matrix encloses granules of magnetic pyrites (troilite?), granules and plates of nickel-iron, and numerous dark grey crystalline spherules, averaging $\frac{1}{2}$ mm. in diameter; one little sphere had a breadth of $3\frac{1}{2}$ mm. They have an excentric-radiate or contorted-radiate

* F. E. Geinitz, 'Jahrbuch für Mineralogie,' 1876, 608.

† E. Cohen, 'Verhandl. Naturhis. Med. Vereins zu Heidelberg,' 1878, II. Heft 2.

structure. A freshly broken surface of the stone is studded with these chondra, and they are easily removed from the matrix. As regards their mineralogical aspects, the spherules are found to be of two kinds. One consists of small prisms of a rhombic mineral which has all the appearance of a variety of enstatite; others are found to possess all the properties of olivine. These two minerals also constitute the greater portion of the matrix. The augitic mineral occasionally contains opaque granules and colourless microlites, the olivine pores or cavities, some of which, the author states, appear to contain fluid. Metallic particles are rarely, if ever, found in the spherules themselves. An accessory mineral, transparent, pure, and with well-defined edges, is also to be found in the meteorite. It differs from the rhombic augite in exhibiting no cleavage fissures, from olivine by the smoothness of its polished exterior, and from both of them by exhibiting distinct pleochroism with absorption; one tone being colourless, the other pale red with a faint tinge of brown. It appears to be rhombic, and shows a close resemblance to a variety of hypersthene found by Cohen in a gabbro from South Africa. The Zsadány stone resembles those which fell on several different occasions at Lancé, Gopalpur, and Pultusk.

By treatment with acid a considerable quantity of the silicate was decomposed. The analysis of the portions thus separated gave the following numbers:—

	Soluble Portion.	Insoluble Portion.
Silicic acid	44·56	56·71
Alumina	trace	2·32
Iron oxide	17·54	13·21
Lime	trace	1·77
Magnesia	37·90	25·99
	100·00	100·00

The stone, therefore, appears to consist to the extent of three-fourths of a bronzite, the remaining fourth being an olivine, in which the equivalents of MgO : FeO are as 3·89 : 1, or approximately that which is often met occurs in meteoric olivines.

1876, *June 28th*, 11.50 *a.m.—Ställdalen, near Kopparberg, Örebrolän, Sweden.**

Attention has already been directed to this remarkable fall of aërolites (see Report for 1876). The total number of stones found is eleven, and they weigh collectively 34 kilog. Lindström finds the total composition of a portion of one of these stones to be—

Silicic acid	35·71
Phosphoric acid	0·30
Alumina	2·11
Chromium oxide	0·40
Iron protoxide	10·29
Manganese protoxide	0·25
Nickel protoxide	0·20
Lime	1·61

* A. E. Nordenskjöld, 'Föredrag i Mineralogi vid Akademiens årshögtid den 3 April, 1877. ('Aftonbladets Aktiebolags Tryckeri,' Stockholm, 1877.) [See also, 'Nature,' July 19th, 1877.]—G. Lindström, 'Öfversigt af Kongl. Vetenskaps Akad. Förhandl.,' No. 4, 1877, p. 35.

Magnesia	23·16
Soda	0·62
Potash	0·15
Iron	21·10
Nickel	1·61
Cobalt	0·17
Phosphorus	0·01
Sulphur	2·27
Chlorine	0·04
	100·00

Of these ingredients, 4·51 per cent. constitute magnetic pyrites, and 14·65 per cent. nickel-iron, the composition of which appears to be—

Iron	90·78
Nickel	8·29
Cobalt	0·88
Phosphorus	0 05
	100·00

The portions (I.) gelatinisable with and (II.) unacted upon by acid have the following composition:—

	I.	II.
Silicic acid	36·76	57·37
Phosphoric acid	0·83	0·07
Alumina	0·13	5·07
Iron protoxide	20·35	8·03
Nickel oxide	0·60	—
Manganese oxide	—	0·63
Lime	0·64	3·41
Magnesia	40·47	23·54
Soda	0·18	1·38
Potash	0·16	0·23
Chlorine	0·13	—
	100·25	99·73

In the soluble portion the oxygen ratio of acids to bases is 20·08 : 21·16, and in the insoluble part 30·64 : 15·08. In addition to olivine and bronzite, this meteorite appears to contain an insoluble felspar and a little apatite.

1877, *May* 17*th*, 7 *a.m.*—*Hungen, between Steinheim and Borsdorf Provinz, Oberhessen.**

An eye-witness of the fall of one of these meteorites states that, as he was passing through a wood, on his way from Steinheim to Borsdorf, he heard a noise as of thunder, although the sky was cloudless, followed by a humming, hissing, whistling sound, such as would be caused by a number of stones rapidly rushing among the trees. One stone struck a pine tree close by him, severed a branch about the thickness of the finger, and fell at his feet. It was some time before he could convince himself that the object before him was not alive, but when he at last ventured to raise it from the ground he found it was cold.

Buchner visited the locality five months later and found a second stone, weighing 26 grammes. The first must have weighed more than 86

* O. Buchner and G. Tschermak, 'Mineralogische Mittheilungen,' 1877, 313.

grammes, and a portion of it weighing 73·26 grammes has been deposited in the mineralogical collection of the University of Giessen. It has an irregularly triangular and flattened form, and less than one quarter of the stone has apparently been removed. It should be stated here that Buchner learned from several who were able to bear witness to the occurrence, that the sound attending the descent of the meteorites proceeded in a direction from N.W. to S.E. The freshly fallen leaves of mid-October rendered hopeless further search for the other stones which must have fallen.

The crust of the meteorite is dull black and thin, and exhibits here and there granules of nickel-iron. The fractured surface displays a grey, occasionally brownish, matrix, which is traversed by a very thin but very conspicuous brilliant black band of material; it runs obliquely to the flattened side of this stone, and is also found in the smaller mass, picked up five months later, which evidently never formed part of a larger meteorite. On another part of the fractured surface of the larger stone, a second black line, parallel to the first, but less brilliant, is to be seen. Abundant particles of nickel-iron and troilite are met with; and the crust appears to consist, to the extent of one-half, of the metallic alloy. Examination under the microscope shows the ground mass to be colourless and transparent and to be fissured in every direction. It appears to consist of olivine. Some olivine spherules are quite conspicuous, surrounded either by the black material or nickel-iron; other chondra have a banded or radiate structure, like those observed by Tschermak in the aërolites of Shergotty or Gopalpur, and appear to be bronzite; and lastly, there are spherules of a homogeneous grey translucent substance, devoid of or rarely traversed by fissures. Buchner states that the meteorite of Hungen, while a member of the most common class of meteorites, can easily be distinguished from those which fell at Agen, Girgenti, New Concord, Kuyahinya, Kräkenberg, Pultusk, and many others which he mentions.

The smaller stone was presented to the Vienna Collection, and forms the subject of a few notes by Tschermak in an appendix to Buchner's paper. He describes its characters, which nearly approach those of the Pultusk meteorites. The black crust has the unusual thickness of 1·5 mm., and encloses particles of nickel-iron, granules of magnetic pyrites (troilite?), and even lustreless chondra, which may consist of chromite or picotite. The transparent minerals constituting the chief mass of the stone are of three kinds : 1. *Olivine*, recognised by its rectangular cleavage and few included minerals, and by its contributing but little to the chondritic character of the stone; 2. *Bronzite*, in granules and aggregated crystals, showing a prismatic cleavage, the latter being either barred or radiate, or contorted and forming the greater number of the chondra; and 3. *Diallage*, for such Tschermak believes to be a brown mineral, forming angular fragments, which are found not to be rhombic and to resemble an augite. The chromite occurs in granules and in larger crystals than are met with in other meteorites.

This interesting stone has not yet been analysed.

1877, *June.—Cronstadt, Orange River Free State, South Africa.*

All that I have yet been able to gather respecting this occurrence is, that a shower of stones fell near Cronstadt in June last, in a wooded district, so that few of them could be collected. One of them is preserved in the British Museum.

1877, *October 13th, about 2 p.m.—Soko-Banja, N.E. of Alexinatz, Servia.** [Long. 20° 53′ E. of Greenwich; Lat. 43° 38′ N.]

Doll's paper, which appears in the 'Transactions of the Austrian Geological Society,' contains two descriptions of the fall of meteorites at Soko-Banja, drawn from two different sources. The first, taken from the Servian weekly literary journal, 'Javor,' published at Neusatz, is written by an eye-witness of the occurrence, who states that the 13th October was fine, and the sky clear, and that about two in the afternoon a noise as of thunder was heard resembling batteries of cannon firing briskly. The sound was followed by a violent concussion of the air, and then a number of aërolites were strewn over the adjacent region. One, weighing 10 okas ($22\frac{1}{2}$ Austrian pounds), fell in front of a house in Soko-Banja, and was driven deep into the earth; a second, which touched the ground at Scherbanowaz, near the Rtanj Berg, weighed 30 okas ($67\frac{1}{2}$ Austrian pounds), and is the largest mass which was collected. The peasants at Rtanj state that one which fell in that locality was of the size of a sack of flour, and that by striking against the rocky surface it was dashed to fragments. From the second and later report, provided by Ritter von Stefanowitsch, of an inquiry instituted by some scientific men from Belgrade, it appears that two explosions, like salvoes of artillery, were heard, accompanied by a brilliant display of light such as attends the bursting of shells. A dense black smoke was observed at a considerable altitude, which broke up into three columns, and gradually changed to a white smoke. The noise lasted for some time, and then the sound resembled the firing of musketry. The air appeared to be shaken. Soon after the explosion commenced a number of meteorites fell to the ground over an area a mile and a half in length and half a mile in breadth. The following masses have been collected:—

1. One, weighing 23 okas, fell in the village Scherbanowaz, and penetrated the soil to the depth of four feet. (This is the one mentioned in 'Javor.')
2. One, weighing 15 okas, fell near the vineyard at Soko-Banja, and reached a depth of three feet. This appears not to be the mass referred to in 'Javor.'
3. Two stones found at Blandija.
4. A fragment, weighing 2 okas, was found at Prevalač.
5. A meteorite of small size fell at Gradič (Prevalač and Gradič are hamlets, west of and close to Soko-Banja).
6. A number of pieces of various sizes fell at Dugopolje, and several very small stones are reported to have fallen on the Djeviza Planina.

One fragment, 2 okas in weight, fell on a pear tree, and then descended to the ground; a man who was under the tree took it in his hands, and received the impression that the mass was still warm.

The meteorites were sent to the Natural History Museum at Belgrade. Döll's paper contains two little maps indicating the area over which the stones were strewn. He describes a small specimen which came into his possession: the matrix is bluish grey and compact, enclosing spherules which vary in size from that of a millet-seed to that of a hare-shot, and which project from the fractured surface. But little nickel-iron or

* E. Döll, 'Verhandl. der K.K. Geolog. Reichsanstalt,' 1877, No. 16, 283. S. M. Losanitch, 'Berichte der deutschen chemischen Gesellschaft,' 1878, xi, 96.

magnetic pyrites (troilite?) could be seen. He noticed patches of a brown colour, which he considers characteristic of this meteorite.

Losanitch, in his communication to the Berlin Chemical Society, which appeared subsequently, states an interval of 25 seconds elapsed between the appearance of the meteor and the first explosion, which was followed by *two* others. The explosion occurred at an altitude of 7000 metres. The path of the meteor made an angle of 220° 50′ with the magnetic meridian, and followed a course from N.E. to S.W., with a very rapid descent. The track of the meteor has been calculated by Kleritj, and the details are to be found in 'Glasnik,' the journal of a Servian learned society. He makes the entire weight of the stones, whole and in fragments, to weigh 80 kilog.

All the meteorites are coated with a black rough vitreous crust, 0·5 mm. in thickness, exhibiting numerous depressions. The interior consists of spherules of various sizes, some brown, some yellow, cemented together by an ash-grey material, and presents the appearance of a trachytic lava. In polished sections, prepared for microscopic examination, nickel-iron in granules, hackly fragments and filiform particles are to be recognised. The specific gravity of the meteorite is 3·502. The meteorite consists of—

	I.	II.
Nickel-iron	3·8	3·7
Silicates	96·2	96·3
	100·0	100·0

and a little iron sulphide. A fragment of the nickel-iron, which was separated from all adhering silicate, possessed the composition—

Iron	= 78·13
Nickel	= 21·70
Copper	= 0·17
	100·00

This is a high percentage of nickel; the ratio of the metals is—Fe : Ni as 4 : 1. The iron sulphide was found to be the mono-sulphide, and to contain 63·84 per cent. of iron; theory requires iron = 63·64 per cent. Analyses of the complete meteoric rock, containing the metallic alloy and iron sulphide, but freed from all trace of crust, were made—(1) by treating it with hydrochloric acid and caustic potash, which removed constituents amounting in three cases to 60·50 per cent., 61·44 per cent., and 61·79 per cent.; and (2) by determining the ingredients of the portions (I.) acted upon by, and (II.) withstanding these reagents. They are as follow:—

	I.	II.
Silicic acid	32·24	56·66
Iron protoxide	28·41	23·55
Manganese oxide	0·20	0·003
Magnesia	30·53	20·84
Soda	0·43	—
Potash	0·09	—
Iron	0·70	—
Nickel	0·17	—
Iron monosulphide = 6·78 { Fe =	4·31	—
{ S =	2·47	—
Chromite	—	0·11
Phosphorus	—	trace
	99·55	101·63

Neither alumina nor lime appears to be present in this meteorite, and augitic and felspathic constituents are consequently absent. The oxygen present in the two silicates amounts to—

	I.		II.
Silicic acid	17·19		30·22
Iron protoxide......... 6·31 / Magnesia............... 12·21	= 18·52	5·23 / 9·33	= 14·56

The soluble portion, therefore, is an olivine, having approximately the composition represented by the formula $2(\frac{2}{3}MgO, \frac{1}{3}FeO), SiO_2$; and the insoluble part a bronzite of the form $(\frac{2}{3}MgO, \frac{1}{3}FeO), SiO_2$; the ratio of iron oxide to magnesia being the same in both silicates.

1877, *December 26th*, 8 *a.m.—Between Hohr and Ballendar, near Coblentz.**

A correspondent of the 'Coblenzer Zeitung,' dating from "Höhr, 27th December," writes that on the preceding day two meteorites fell near the road leading to the former frontier, in the direction of Ballendar, and that the fall was attended by a very characteristic explosion. The editor of the above journal has been unable to gather any further particulars of the occurrence beyond the fact that the stones fell in a wood, and could not be discovered.

General Directions, and Instructions to Observers, for Recording Meteors and Aerolites.

Much industrious labour and attention has of late years been bestowed by experienced and eminent astronomers on collecting and discussing meteor observations, and on deducing from them a great variety of very important astronomical conclusions. Materials of constantly increasing interest have in consequence accumulated somewhat rapidly in recent years towards the extension and development of the astronomical theory of these bodies, a clear and exact exposition of which, dealing only with the most positively ascertained and clearly established features of their history, would here be too wide and extensive a subject to be properly discussed at length. The astronomical problem of their origin, which is set before us by the appearances of meteors of the most dissimilar descriptions, is naturally too extensive and too diversified a question to be included in a single theory, or to admit of only a single explanation; and it is not at present so much to the causes and to the origin of their occurrence that it is desired to direct particular attention, as to the best means of observing and describing accurately the various notable appearances which they present, and to the most convenient and effective methods to be followed for preserving useful records of their ordinary and extraordinary exhibitions.

The phenomena of luminous meteors may be comprehended, in the first instance, under the leading titles or descriptions of a few general and appropriate designations (long since introduced, and still very convenient to rate and record them by distinctly, although not completely and sufficiently), for the immediate practical purposes of their registra-

* 'Coblenzer Zeitung,' December 29th, 1877.

tion. In their orders of magnitudes meteors may thus be distinguished as either—

I. *Telescopic meteors*, only rendered visible to the eye by the aid of telescopes;

II. *Shooting-stars*, visible to the naked eye, and comparable to the different apparent magnitudes of the fixed stars in brightness;

III. *Bolides and Fireballs*, or very luminous meteors, comparable in brilliancy to the planets Jupiter and Venus, and to the different phases of the moon, and sometimes even rivalling the sun by appearing with much splendour in broad daylight; the term *Bolides* being usually applied to the smaller, and *Fireballs* to the larger kinds;

IV. *Detonating, or "Aërolitic" meteors*, fireballs which produce an audible explosion, like a distant cannon's, a peal of thunder, or an earthquake's shock, by their concussion with the air; and which differ accordingly from the last (as "forked" lightning often does from distant or "sheet" lightning) only by the thunderclap that not unfrequently reverberates from fireballs of the largest and brightest class; or finally as—

V. *Stonefalls* and *Ironfalls* (the latter very rare occurrences), or the falls of *meteorites*, either singly or in a shower, it may be, of many thousands of fragments from a fireball, which, especially if seen in the daytime when these occurrences are usually observed, is almost always a large meteor of the last-named description.

For each of these different kinds of apparitions it is necessary to furnish separate and somewhat independent directions and instructions to enable good and useful accounts of their phenomena to be preserved.

I. *Telescopic meteors* are not unfrequently noticed during astronomical observations; and some singular records of the occurrence of such bodies by day and by night in dense showers have been placed on record. The point to which a telescope is directed (in R.A. and Decl.), with the hour when such an object presents itself, and its brightness compared with that of fixed stars seen with the same telescope, is to be stated; and the position-angle of a diameter, or radius of the field of view drawn parallel to the direction *towards which* the meteor shot should be determined in the degrees or quadrants usually adopted by astronomers (making the allowance for inversion of the image which the telescope requires) with as much precision as can been ensured. The length of path, if not prolonged beyond the view of the telescope, can be stated by comparison with the known width of its field in minutes or parts of a degree of arc; and deviations of straightness, change of brightness and appearance of the head, during its passage, as well as the persistence on its track of a streak or of sparks, if visibly remaining, should be noted, with the duration in seconds, as nearly as it can be estimated, of the meteor's flight while the nucleus was in sight. A streak will often mark the line of passage of a meteor which crosses the field of view too swiftly to be followed with the eye, and the breadth of this light-streak in minutes or seconds of arc should then be noted, with its brightness and duration, appearance and changes of appearance, and with the magnifying power of the telescope employed. A star spectroscope should also be used

if possible to observe its spectrum, if it is of sufficient brightness and duration.

As it has been contended that telescopic meteors are rendered visible by optical power at vastly greater distances from observers than ordinary shooting-stars can be seen, and that their apparent speeds and lengths of path are, under these circumstances, greatly reduced by distance and rendered inferior to those of the majority of meteors, observations of small telescopic meteors with short slow courses, if they occur, should be carefully recorded, in order to determine if they are principally seen at low apparent altitudes, and moderate real heights only, or with equal frequency at all angular altitudes above the horizon, and therefore at all possible heights above the earth's surface to which the use of astronomical telescopes of the highest powers and apertures enables us to extend our sight.

II. *Shooting-stars* are observable with a certain frequency on all cloudless nights. The result of an attentive watch on such occasions to note their frequency by a few hours' observation, especially if in the absence of the moon, is of great value; but the fitful activities of many meteor showers often combine together to render a rate of frequency concluded from a single hour's observations deceptive and misleading; and attention must be paid to noting the middle-time of the watch to the nearest quarter of an hour, as upon its lateness in the night, as well as on the season of the year, depends the average horary number which a single observer may expect to see.

In comparison with that of an evening hour at six o'clock, the number visible in the same morning hour is about double, and nearly as notably greater for a midnight hour in August or September, than for one in February or March. For an average midnight hour in the whole year, Quetelet estimated the horary number visible to one observer in a European station as about six meteors; and a greater number than twelve or fifteen meteors seen in an hour at an average time of night and season of the year, may be regarded (though not certainly) as indicating an active exhibition of some special meteor shower. It is to the prominency which such exceptional phenomena sometimes reach as meteoric spectacles, that the distinction which has arisen between shower meteors and sporadic shooting-stars is entirely owing; and from the partial extent of our present acquaintance with the directions, intensities, and durations of multitudes of weaker descriptions of such showers, innumerable shooting-stars must still be regarded as "sporadic" until well-determined centres from which they appear to diverge accurately can be definitely assigned to them.

To note and reduce *shower meteors* to their radiant-points is a task of little difficulty to an observer already conversant with the positions of the principal fixed stars, and of the constellations. But the use of star charts properly adapted for projecting meteor-paths soon familiarises unpractised observers with this preliminary preparation; and facility is soon acquired in drawing upon a map the initial and end-points of a meteor's track, and in prolonging through these points a straight line backwards on the map, or tracing, to show by a simple inspection of a number of these lines their common crossing point, or the focus of emanation of the meteor shower that they belong to, in the sky. The natural impressions of direction are of slender use in endeavouring to fix this point correctly by the eye alone, retracing the meteor's track among the stars themselves; a

straight wand held up to direct it, soon assuring an observer that the eye without an assistance of this kind is a very fallacious guide. But by using for the picture of the stars the same principles of plane perspective representation which are used habitually for pictures of ordinary objects, the straight wand and the straight path of the meteor in the sky when drawn upon the map are also straight lines, and may be prolonged, not only with greater ease to other parts of the map than in the sky, but also by a pencil they may be marked indelibly upon the page or sheet, so that comparison with many successive lines thereupon becomes not a doubtful and uncertain, but an easy and perfectly unerring operation. In accordance with the most recent practice of Herr von Konkoly, of Komorn, in Hungary, as well as of the late Professor Heis, the Committee has prepared celestial charts in plane perspective, with whose assistance the positions of the centres of departure of different meteor showers can be easily verified and investigated by observers, and further particulars regarding their intensities and durations may be ascertained.

As a guide for the selection of meteor showers for special study, the Committee refers observers to the Key Map and General Catalogue of all such known meteor systems published by the British Association in the volume of its Annual Reports for the year 1876, by Mr. Greg; where the relative importance, as resulting from the richness and constancy of meteor-showers, in returning at the annual epochs of their visibility is stated and represented. The principal characteristics of the meteors, including their colour and brightness, the apparent lengths, speeds, and durations of their flights, and the presence of sparks or streaks in their tracks, have hitherto been very little noted, and such peculiarities belonging to the showers, as well as their dates of principal abundance, and the exact positions of their radiant points, form very important and interesting subjects of inquiry.

The observation of *sporadic shooting-stars* is necessarily less attractive and suitable to ordinary observers than mapping the apparent paths of meteors belonging either to the well-known major and "special" or to some minor annual meteor showers. But as regards the observations, the method of procedure is the same, with the exception that long-continued watches maintained for a whole night are, in general, indispensable to a successful collection of their tracks by a single observer. Should no indications of a new shower accidentally occur by unusual frequency of meteors from a new radiant-point in evening watches of a single night, yet the detection of such a shower is no uncommon recompense of an observer's vigilance in a morning watch, or among the meteor-tracks recorded on a few successive nights. As the same remark applies to the accidental vision of bolides and fireballs, the same instructions will suffice, and the same course may be pursued most advantageously by observers in recording sporadic shooting-stars as in describing large meteors that may be occasionally observed; and these in the next paragraph will be more fully indicated and described.

III. *Bolides and Fireballs* have the singularity among meteors, and the pre-eminence over shooting-stars of attracting the attention of a great number of observers. This is also the case with meteor showers when they are sufficiently abundant to lead to general observations and to conclusive determinations of their radiant-points, although poor and scanty showers escape this identification for lack of a sufficient number of observations. As, however, by the displacement of his point of view, a

fireball seen by every new observer appears to him in a different part of the sky, or virtually as another meteor, it follows that both for fireballs and for very scanty meteor showers the multiplication of observers of the phenomenon by increasing the number of meteor tracks belonging to the same radiant-point, suffices, when they are sufficiently exact and numerous, to fix its place exactly, and to determine the direction from which the meteor shower or the fireball took its flight. Exactness in describing a fireball's apparent path by the stars or otherwise is the more desirable and important, because no doubt exists that *any two* such recorded appearances of its path must belong to the same meteor; and that, therefore, when prolonged backwards to their intersection, if they are fairly accurate they will be sufficient by themselves to point out its radiant-point or the direction and distant origin of its real course with satisfactory precision. But even a dozen meteors of a poor and scanty star-shower only afford presumptive evidence of their having a common direction and radiant-point at the centre of divergence of their tracks, as scarcely any other evidence but this divergence, in general, exists of their belonging to a common system; and to increase its probability a fresh number of meteors of the same shower must be noted, and must be traced back to the same centre of divergence. Observations of sporadic shooting-stars must, therefore, be greatly multiplied (however accurate they may be), while two accurate observations only of a fireball are absolutely necessary to determine the exact direction, together with the height and distance, and the other particulars of its flight. This fortunate concurrence of two or more simultaneous observations is sometimes recorded of a shooting-star; and then the real direction of this meteor is as certainly determined as that of a fireball, and the orbit of either (which is the sole clue that we can gain to its astronomical history) is known as certainly as the orbit of a meteor stream. But such accuracy of observation as would allow us to depend upon two observations only is seldom, if ever, reached by observers, either of shooting-stars or fireballs, and of the latter class of meteors especially, many scores of accounts are annually indited by unpractised observers, containing no material data (or only conflicting ones) of the meteors' courses, while the accordant notes occasionally furnished of shooting-stars by well-skilled observers show the difficulty, if not the hopelessness, of arriving by two observations at anything approaching to the accuracy of instrumental determinations. With rare exceptions, therefore, a large and abundant collection of observations is needful for exact comparisons, which it is the object of the Luminous Meteor Committee appointed for this purpose by the British Association to obtain, by providing observers with suitable forms of registry, maps, and instructions for recording the appearances of fireballs and ordinary shooting-stars. The Committee distributes to observers who apply for them printed Forms of Registry and Directions, as the most convenient and efficient means of assisting them in systematic observation. For the best means of noting and describing exactly the appearances of large meteors the Committee also directs attention to a letter in the 'Scotsman' (daily newspaper) of May 1st, 1878, by Professor Herschel, from the full paragraphs of which, pointing out the features of position and appearance to be recorded, it is not necessary to reproduce here a long series of appropriate suggestions, as instructions for recording large meteors and ordinary shooting-stars will be found sufficiently illustrated in the Committee's printed Forms of Registry and

in the remarks on the process of mapping and projecting them graphically on star charts which have been offered in the last section regarding them. The following recommendations to observers on occasions of the occurrence of aërolitic meteors, and of the falls of meteorites, describing the points of information most desirable to be recorded regarding their characters and appearance, have been drawn up at the request of the Committee, to conclude these practical directions, by Dr. Flight.

IV. *Detonating, or Aërolitic Fireballs.*—In recording observations on the passage of a meteor across the sky, the points which it is most desirable to arrive at are: such data as will allow of our definitely noting the direction of its path and its point of extinction, the duration of the luminous phenomenon, and of individual phases of it, the apparent magnitude of the meteor, the luminosity as compared with other brilliant objects, and the changes which it may itself exhibit in this respect during the transit, the duration of the train (or "streak"), and the changes it may undergo before extinction (whether it fade away simultaneously along the entire length, or break up into a chain of luminous fragments); also, in cases where the streak is one of great persistence, the manner of its final disappearance; again, when the meteor has been observed near the time of sunrise, or sunset, what change it wrought in the appearance of the visible train by the increasing, or waning, light of the sky. The sound attending its passage, if any, and the character of the sound, as regards intensity and duration, whether single and well defined, or a series of minor explosions closely following one another. And finally, the time of appearance, and that of the interval before the explosion is heard.

While it is barely possible for one observer to record all the data referred to, he should not fail to note such of them as may have come clearly within his observation. Other spectators may have remarked what he may have missed, and their joint observations may enable us to arrive at a complete physical history of the meteor in question.

It is desirable to determine two points of the track of the meteor, as far asunder as possible—the points of appearance and extinction are to be preferred—and to indicate the former by reference to some star or constellation which it overlies, and the latter by some object on the horizon against which it is projected. In cases where the meteor is seen in daytime, the data to be arrived at are the point of appearance and its angular altitude. The former may be estimated by noticing what conspicuous object lies vertically below it on the horizon: a village or a mountain peak. The more distant the object is from the spectator, the more accurate will be the determination of this element of the observation. If objects to which reference can be made should be wanting, the direction may be temporarily noted, and subsequently determined by the aid of a compass-needle. To learn an angular altitude we dare not trust general conclusions, however carefully arrived at; even experienced observers may be misled in such cases. If a vertical object, say the roof of a house, or the top of a tree, happen to lie in the direction under consideration, the observer should approach it till the line of sight of the origin of the course of the meteor skirts the summit of the terrestrial object. The observer has now to determine how far he is removed from the object selected, its vertical height above the plain on which both are situated, and the distance above the ground of his own eye, in order to be in a position to determine the angular elevation of the point of appearance of the meteor, the position of which he desires to ascertain.

The apparent path of the meteor is often represented by a line like a bow: in other words, the meteor apparently ascends, culminates, and then takes a downward course. This motion is, however, for the most part, as has been stated, apparent only; and is a consequence of the varying inclination which a straight line appears to form with the horizon at different points along its course. The observer should endeavour to determine as accurately as possible the apparent inclination at those points of the meteor's arc, or line of flight, which can be most readily identified, such as the beginning and the end of the track, or those where a break in the luminous train occurs, as well as that portion which lies parallel to the horizon. The point of extinction should especially be noted, and this is the more readily accomplished from the fact that the attention has been steadily directed to observing the luminous phenomena preceding it. In regard to the point of appearance, it is of importance to determine whether the impression made on the observer was that he had witnessed the blazing forth of the meteor in the sky, or whether the meteor had entered his field of vision, and a portion of its luminous track had not been seen by him.

It is, moreover, of importance to arrive at a knowledge of the length of time occupied by the meteor in traversing the sky; this may sometimes be learned by counting the ticks of a watch, or by advancing in the direction of the object at a uniform rate, and counting the paces taken during the observation. It should also be noted whether the meteor moves onward with an accelerating or diminishing velocity.

The brilliancy of a meteor larger than the fixed stars of different magnitudes can most conveniently be compared with the light of Venus or Jupiter; and in the case of the largest meteors, with the apparent brilliancy and magnitude of the moon in her several phases. The colour exhibited by the meteor should also be carefully observed, and any change of hue along any part of the path should be recorded. The luminous train left after the disappearance of the meteor is sometimes very persistent, and often terminates in a cloud, faintly visible. Any peculiar structure exhibited by the train, or cloud, should be sketched on paper.

The sound attending the flight of a meteor usually consists either of several distinct explosions, or a crackling rolling detonation. The closest attention should be given, after the extinction of the meteor, for the arrival of the sound and the length of the interval, carefully noted with the watch.

Of the many points which, as has been shown, it is desirable that a record should be made, an individual observer can obviously determine but a few; all those of them, however, to the accuracy of which he can certify, are of value, since other observers may supply the missing data, and the whole may be collected.

V. *Stonefalls and Ironfalls.*—If a meteorite have fallen, visit the spot where it struck the ground, and examine the hole which it has formed. Determine the depth, and especially notice the direction of the cavity in respect to the points of the compass. Ascertain whether the meteorite was removed from the ground soon after its descent, and whether any observation had been made at the time respecting its temperature. Make a note of the material forming the surface layer, and state whether it was moist or dry. Further inquiries in the neighbourhood may lead to the discovery of other meteorites which had fallen at the same time,

and at points not unfrequently miles distant. They may vary greatly in size; and stones as small as a pea or bean may be sought for. The meteoric masses with which we are at present acquainted are—1, heavy metallic bodies, covered with a dull, often black, crust, sometimes having a pitted surface (meteoric iron); 2, heavy metallic masses with a more crackly exterior, and hollows in which the presence of rocky matter can be recognised (siderolite); 3, and rock-like fragments, often grey, sometimes white, and occasionally, although rarely, black in the interior (sometimes little brilliant particles of metal are observed, disseminated through the matrix), and always coated on the exterior with a black fused crust, sometimes dull, sometimes lustrous (meteoric stone). Meteoric stones are sometimes broken by the fall and the interior revealed; by the disruption of a stone during its descent, the freshly fractured surfaces are exposed to intense heat, and become of a darker hue, but have not a glaze like the actual crust. When fragments of the same shower of stones have fallen some miles asunder, such partially altered surfaces should be fitted together, in order to see whether they form portion of a larger mass. The fall of a light chocolate-brown substance, resembling amadou, enclosing little brilliant particles of meteoric iron, may accompany the fall of meteoric stones.

Sixth Report of the Committee, consisting of Sir JOHN LUBBOCK, *Bart.*, Professor PRESTWICH, Professor BUSK, Professor T. MCK. HUGHES, Professor W. B. DAWKINS, Professor MIALL, Rev. H. W. CROSSKEY, Mr. H. C. SORBY, *and* Mr. R. H. TIDDEMAN, *appointed for the purpose of assisting in the Exploration of the Settle Caves (Victoria Cave). Drawn up by* Mr. R. H. TIDDEMAN *(Reporter).*

YOUR Committee have to report that the Settle Local Committee, with whom they have the pleasure of co-operating, have spent in the course of the year, from September 3rd, 1877, down to the end of June of this year (1878), 169*l.* 19*s.* 10*d.*, of which sum 100*l.* was granted by the Association at the Plymouth Meeting. The remainder of the money has been raised by private subscriptions. At the request of the Settle Committee Sir John Lubbock has kindly consented to be Chairman of the Local Committee in succession to the late Sir James Kay-Shuttleworth.

The work has gone on nearly all the year from September 3rd, 1877, with few and very short intermissions. On the 22nd of June of this year owing to the failure of our funds we found it necessary to discontinue for a time. Fortunately as it was haytime the workmen could leave without detriment to themselves. Later on, as the result of an appeal made, a little money came in and we were able to take the men back again near the end of July.

The Committee have to make this year an important announcement, the correction of a considerable but unavoidable error. It is contained in the following communication from Professor Busk to the Secretary.

32, Harley Street, August 8th, 1878.

My dear Tiddeman,—I received from Toulouse two ursine Fibulæ, of abnormal size, which in the part corresponding to the "fragment of contention" so closely resemble it, as to leave little room for doubt that the latter is, or may be, in reality ursine and not human.

I am disposed, therefore, to acknowledge that my diagnosis of the Victoria Cave bone was in all probability erroneous, and that, so far as such an imperfect witness can testify, the preglacial existence of man must rest upon other evidence.

I am unable to leave town for the Dublin Meeting, but shall be glad if you will make my change of opinion in this matter known. In returning the Victoria specimen I will also send one of the Toulouse bones, which are very remarkable, and as regards size widely different from any I have before seen; and with relation to their size it is to be remembered that in your Collection* is one of the largest ursine crania (of the *ferox* type) with which I am acquainted.

With kind regards,
Yours very truly,
George Busk.

It will be remembered that this bone was found by Professor Busk and Mr. James Flower to bear the strongest possible resemblance to a rather abnormal recent human fibula in the Museum of the College of Surgeons, and was also considered not unlike the fibula in the famous Mentone Skeleton. It was, therefore, considered an undeniable proof of the existence of man with the extinct mammals in Yorkshire. Professor Dawkins supported Professor Busk and Mr. James Flower in this determination,† but we must also add that he was the first to express doubts about it, and further inquiries and examination instituted by him and Professor Busk lead your Committee to the conclusion that any arguments based upon its supposed human character must unreservedly be given up. If it bear an equally good resemblance to abnormal ursine and human fibulæ, it is clearly not a sufficient foundation upon which to build any views as to the existence, or non-existence, of man at a remote period.

In stating this we desire to call especial attention to the fact that this bone is not the only one found in the Victoria Cave which can be supposed to have a bearing on the antiquity of man, and his existence in Britain before the last great cold period had passed away in the North of England. Many bones found in the Cave cracked and split, as savages split them, for the extraction of marrow, have been very properly passed by as at best very doubtful evidence, such fractures possibly owing their existence to falls of rock upon bones lying on the floor beneath. But we cannot so easily explain away the evidently artificial marks upon the two small bones found in the Hyena-bed, and already referred to at length in the postscript to last year's Report (pp. 218–220).

Nor even were this evidence to be got over, can we rightly lay aside the arguments founded on Physical Geology which result from the facts partly obtained in the Victoria Cave Exploration. They are these—1. The existence of certain areas in the North of England where there is abundant evidence of land glaciation of a comparatively late age. In the river-deposits of these areas the earlier pleistocene mammals are never found

* At Giggleswick Museum. † 'Cave-Hunting' (1874), p. 120.

in the open country, and they are equally remarkable for the absence of palæolithic implements, although we know that the same mammals, if not palæolithic men, have overrun that ground. 2. The existence of other areas in the South and East where there are not distinct traces of so late a land-glaciation, but where the remains of the same animals and of palæolithic implements are abundant in the river-gravels in the open, as well as in the caves. We can hardly suppose that this contrast in the two areas can be due to the same destructive powers of nature working with greater intensity in one than in the other, and we are brought to the conclusion that an agent was at work in the one area which did not extend to the other. We might cast about for an explanation for a long time, did it not happen that the areas *bereft* of the remains are precisely those which show the freshest and most extensive traces of land-glaciation.

This may be best expressed in tabular form, thus:—

Characteristics	Northern Area	Southern and Eastern Area
Earlier Pleistocene Animals in Caves	Present	Present
Abundant traces of later Land-glaciation	Present	Absent
Earlier Pleistocene Animals in River Gravels	Absent	Present
Palæolithic Implements in River Gravels	Absent	Present

The progress of the work has been carefully noted by Mr. Jackson, our indefatigable Superintendent, and by your Reporter. During the year it has been almost barren in any evidence of animal life in the beds lying below the Hyena-layer. We began working on the left side of the Cave under the old entrance, and thence in the direction of Chamber B. The material consisted almost entirely of large fallen blocks of limestone in yellow sandy clay with, in some places, ochre. A few bone splinters were found here, but they are unimportant, and had probably worked their way down along the rock-wall from the formerly overlying Hyena-bed.

On October 3rd the Settle Committee determined to open ground in a small cave at the foot of the *talus* of the Victoria Cave, on the left as you face it. It was found to contain brown laminated clay with sand at the sides and interbedded with it. Nothing of interest was found, and work was almost immediately resumed at the Victoria Cave as before.

Beneath the yellow sandy clay, on the left already mentioned, we found several large bosses of stalagmite from about two to five feet in height. These evidently indicate an old floor; they rest partly on fallen blocks and partly on others, which may not have fallen and from their form may be part of the solid rock floor worn by a stream. For the present we have left them undisturbed.

The remainder of our work has been for the most part along the right side of the great central Hall, made up of what used to be called Chambers A and D. A row of fallen blocks which had to be blasted lay all along this right wall, but they have not yet been altogether removed. One of the most curious facts noticed in the course of this excavation, is the position of a thick bed of laminated clay which is seen to lie at various angles. Near parallel 5 it was dipping only at a gentle slope towards the right wall, but as the section progressed it inclined more and more, and at parallel 20 dipped at so high an angle as 42°. This is the more

remarkable as it consists of exceedingly fine and beautifully laminated clay, and this high dip is most regular through a considerable distance, and not only close to the fallen blocks, where it might be thought to have been produced by their fall. Some of this clay is exceedingly black, and may possibly be, therefore, derived from the dark Yoredale Shales overlying the Mountain Limestone, which at the period when the clay was formed probably covered a much greater area, and nearer to the Cave, than that which they occupy at present.

Your Committee is of opinion that, though the labours of the year have brought us but a small interest for our money, as compared with the results of former years, the undertaking may be an improving one, and eventually, if persevered in, lead to greater results than any lately obtained by us, and therefore your Committee beg to be reappointed.

One member of the Committee, Professor W. B. Dawkins, requests that his dissent from this Report be distinctly recorded.

Report of a Committee, consisting of Mr. GODWIN-AUSTEN, Professor PRESTWICH, Mr. DAVIDSON, Mr. ETHERIDGE, Mr. WILLETT, *and* Mr. TOPLEY, *appointed for the purpose of assisting the Kentish Boring Exploration. Drawn up by* Mr. GODWIN-AUSTEN.

I REGRET to have to report that during the past year nothing whatever has been done to warrant an application for any portion of the grant placed at the disposal of the "Kentish Boring Exploration," the more so as results have been arrived at by private enterprise which certainly give the information sought for—namely, whether Palæozoic rocks, and what might next underlie the chalk formation of some part of the S.E. of England, as is the case in Belgium and the North of France.

So soon as it was ascertained that at the corner of Tottenham Court Road and Oxford Street there occurred characteristic upper Devonian strata at about 1000 feet from the surface, the whole question, and all that it involves, seemed to be answered, and the supposition of the report of the Coal Commission, which as far back as 1871 had indicated the line of the Thames Valley as that of the course of the said Palæozoic band, was proved to be correct.* One single point remained in doubt, namely—in which direction from the end of Tottenham Court Road may the mountain-limestone and coal-measure formations be looked for? It may be asked, why is it to be certainly inferred that any such sequence obtains at Tottenham. A satisfactory answer, from our acquaintance with the physical and geological history of the European area, in early times, can be given to this.

The so-called "Devonian" is not in any sense a distinct formation, except in respect of priority of deposition; it is simply an early stage of a series which in progress of time, and over a corresponding area, passed on to what is known as the "Mountain-limestone series." Across the whole of Central Europe the order of succession of this upper Palæozoic series is the same—namely, 1st, lower carboniferous or Devonian; 2ndly,

* P. 432, qu. 267. "(Mr. Prestwich): You would be disposed then to carry the line of probable coal-measures under the valley of the Thames. Answer: Yes," &c.

carboniferous limestone proper; 3rdly, coal-measures. Whenever one of these occurs the others follow, excepting where, as in places, the coal-measures may have been denuded off, or where this may have happened to the mountain-limestone also.

The angle which the Devonian strata at Tottenham make with the vertical bore-hole being 30°, it is to be inferred that their general direction there is east and west.

The highly inclined position of these Devonian beds was important. Had it been otherwise—had the beds there been found to be lying horizontally—the prospect would not have been encouraging; the two members of the series above the Devonian might be supposed to have been denuded off, or to follow in sequence only at some distance horizontally.

The upper Palæozoic group was not disturbed as we now find it till after the completion of the coal-measures. This holds good from Westphalia, across Belgium, and the North of France, and again in the west of our British area. The preservation of available coal-measures along this line is dependent on their having been enclosed in deep troughs, the results of that east and west linear system of foldings and crumplings to which the whole of this group was subjected. Hence it is that a Devonian limestone reached in the course of such east and west line, and at a high angle (30°), implies, first, that the said band of disturbed strata passes along at that spot, and next that the order of sequence is pretty sure to be regular and complete there. In other words, the Devonian beds come down upon at the Tottenham boring may be safely taken as a continuation of the band which crosses Belgium and the North of France, and are followed as the band is there by the mountain-limestone and coal-measure series in a deep east and west fold or trough.

One more point remains to be ascertained—What is the direction of the dip of the Devonian beds of Tottenham boring? and then any one of the numerous sections which the Belgian and French geologists have given of their coal-measure band may be taken as a guide as to what has happened here; of these, that of the Boulonnais is the best, because nearest. Supposing that it could have been ascertained with perfect certainty that the inclined beds at Tottenham were dipping north, the inference would be that there they had come down on the southern side of a Palæozoic trough, and that the mountain-limestone series would follow next. The thickness of this series in the Boulonnais may be taken at about 400 feet; and the coal-measure-band would come in at about a quarter of a mile or less from the corner of Oxford Street.

On the contrary, had the dip been southerly, then the productive coal-band would occur between Oxford Street and the Thames.

It has been already stated that a single point remains to be ascertained, and the object of the present communication is to show how and where that is to be sought for. First, there must be another boring, and next it must be so near to that at Messrs. Meux's that one may illustrate the other, and so show the dimensions and positions of the Palæozoic bands beneath London; for this purpose the distance from Oxford Street ought not to be more than a quarter of a mile to the north or south.

The Tottenham boring properly considered suggests that the Franco-Belgian Palæozoic band with which coal is associated is continued under London, and is within the narrow limits assigned above. Should such be really the case, it is not supposed that in any such position it could be

made available; the object of completing the results arrived at by Messrs. Meux is to add to our knowledge of the structure of the whole of the band at that place. This would lead us to the direction in which it should be followed both east and west.

Considering the vast importance of the discovery of productive coal-measures from the S.E. of England westwards, both with reference to the present high price of that article in the metropolis and to the many industries to which it would give rise along its whole course, of which the line of country from Liége to Douai may serve as an illustration, the time has come when the results so nearly arrived at at Tottenham should be completed.

Half the money spent upon the Sub-Wealden researches at Netherfield would long since have settled the theoretical speculation—that the coal-measures might be found along the line of the Thames Valley. No blame is imputed to the promoters of the boring. During the inquiry of the "Coal Commission," 1871, much discredit was thrown upon the supposition of an extension of the Franco-Belgian coal band into our S.E. region by the chairman, Sir R. Murchison (see p. 429, and reply of Mr. Dickinson * as to the quality of the Boulonnais coal; also the evidence of Sir R. Murchison, p. 434, and following).

As bearing on Sir R. Murchison's objection, which may be succinctly stated to be, that the formations with which the coal-measures are associated do not cross the Channel, and that, if they do, the coal that they would contain would be worthless, no better than that of the Boulonnais, I would quote from a recent work of the Abbé N. Boulay,† who refers the Boulonnais coal to his upper category or bituminous coal.

Fourth Report of the Committee for Investigating the Circulation of the Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations of England, and the Quantity and Character of the Waters supplied to various Towns and Districts from these Formations, with Appendix, by Mr. ROBERTS, *on the Filtration of Water through Triassic Sandstone; the Committee consisting of* Professor HULL, Rev. H. W. CROSSKEY, Captain D. GALTON, Mr. GLAISHER, Mr. H. H. HOWELL, Mr. G. A. LEBOUR, Mr. W. MOLYNEUX, Mr. MORTON, Mr. PENGELLEY, Professor PRESTWICH, Mr. JAMES PLANT, Mr. MELLARD READE, Mr. W. WHITAKER, *and* Mr. DE RANCE (*Reporter*).

YOUR Committee, during the past year, has continued its inquiries into the water-bearing capabilities of the Permian and Triassic strata, and, in accordance with the instructions they received from you at the Plymouth Meeting, have added the Jurassic rocks to the list of those under inves-

* P. 429., 234. "In point of fact it is so bad that, though used by a few blacksmiths, it has never been extensively worked. (Mr. Dickinson): If the coal is used by blacksmiths it shows that it is good coal."

† P. 11. "Les houilles se répartissent en trois catégories universellement adoptées dans le bassin du Nord: les charbons maigres, les charbons demi-gras et les charbons gras." The Boulonnais coal is referred to this last.

tigation, which now include the whole of the strata lying between the Carboniferous and Cretaceous rocks.

Your Committee have a large amount of information promised them of works and sinkings now in operation by various engineers, and especially by officers of the Government Geological Survey, who are now working over the Yorkshire and Lincolnshire Oolitic districts; and they endorse the opinion expressed by Mr. Edwin Chadwick, C.B., at the Congress on Water Supply held by the Society of Arts, as to the great value of the map of the Survey as a basis for investigation in questions of water supply.

Your Reporter laid before the Congress a table showing the area of each of the geological formations in each river basin, from which it appears that of formations yielding—

	Subterranean waters. Square miles.
Permian and Trias	8,645
Oolite	6,671
Hastings sands, Greensand and chalk	11,371
	26,687

	Moorland waters. Square miles.
Granite, Metamorphic rocks, Cambrian, Silurian, and Devonian	11,455
Carboniferous rocks (without the Carboniferous limestone)	10,080
	21,535

Probably four-fifths of the area of permeable rocks in the first list would yield unpolluted water, and would receive into their mass not less than ten to fifteen inches annually, or a quantity, if six inches only were yielded up in wells, of no less than 240,000 gallons per day for each square mile of surface, and in many districts double this quantity, giving a total for England and Wales far in excess of that required for drinking and manufacturing purposes.

Of the Moorland area it is hardly the province of your Committee to speak, but they cannot but call attention to the costly legislation that all extensive gravitation schemes incur, whether taken from natural lakes, as the proposed Thirlmere scheme for Manchester, or from artificial reservoirs, as the proposed supply for Liverpool from the sources of the Severn; and they would call attention to the fact that the Select Committee on the Manchester Corporation Water Bill recognised the importance of the opinion expressed by the Duke of Richmond's Commission in 1868–69, "That it appears to us that the Legislature should always jealously watch any proposal for a town taking water from a gathering ground at a distance from it, lest by so doing it may deprive other places nearer to such gathering ground of their more natural source of supply."

Cases doubtless exist, to meet which it will be necessary to go to these sources, especially where the populations have been accustomed to soft water, and it would be dangerous to suddenly change the character of the supply. But in the Midland districts, lying on the Secondary rocks, the inhabitants are accustomed to hard water, the quality of which the labours

of your Committee prove might be made, by an efficient system of well-boring, all that could be desired.

Professor Hull has described from time to time the marked south-easterly attenuation of the Triassic and other lower secondary strata, and has given measurements, from which it appears the beds between Liverpool and Warwick, 100 miles, thin out the following rates per mile:—

Red marls	23 ft. per mile.
Lower Keuper sandstone	3 „
Upper Mottled sandstone	5 „
Pebble beds	$6\frac{1}{2}$ „
Lower mottled sandstone	5 „

The gradient is less between Staffordshire and Warwick, half the distance—

Red marls	2 ft. per mile.
Lower Keuper sandstone	1 „
Bunter beds	9 „

With these figures it is interesting to calculate the thickness of the Red beds under the Oolite of Burford, 40 miles south of Warwick; and comparing them with the results actually obtained in the boring made by the diamond process for Mr. Fox, the rate of thinning is found to again largely increase, reaching eight feet per mile:—

	Calculated.		Actual thickness.
Red marls	620	710	428 ft.
Lower Keuper sandstone	90		
Bunter series	Nil.		

The details are as follows:—

Pump-house, Burford, Witney:—

Total depth. Ft.	in.		
		Surface—blue clay and pebbles	Oolites.
38	0	Lost water, at 38 ft.	
		White lias, 1 ft.	
		Blue lias, 1 ft.	
		Lias, 9 ft.	
		Freestone	
		Black limestone	
90	2	Limestone	
		Clay	
148	7	Blue clay, with fossils.	
		„ with fossils.	
		Light lias.	
174	8	Hard lias.	
186	8	Dark green lias, with fossils.	
		Clay.	
		Clay, with pebble.	
		„ with stone binds.	
		„ with shells.	
349	0	Harder clay.	
		Clay, with metal.	
		„ with stones.	
420	0	„ with pebbles and fossils.	
479	10	Clay.	
496	4	„ with minute fossils.	

Total depth. Ft.	in.		
502	0	Blue lias stone.	
		Blue clay.	
		Very soft clay.	
572	0	Stone, one-inch.	
616	3	Blue clay (greenish at 610 feet).	
		Hard lias clay.	
702	0	Clay and stone binds.	
		Hard limestone.	
717	0	Limestone and shale.	
723	7	Soft shale.	
746	10	Soft blue clay.	
749	10	Black shale, 1 ft.	Rhætic.
750	0	Green marl, 6 ft.	Rhætic.
756	0	Gritty sandstone.	Rhætic.
821–3	0	Green marl; Variegated marl; Conglomerate	Trias.
972	8	Variegated marl; Red and blue marl, gypsum	Trias.
1047	0	Red marl and gypsum	Trias.
		Red marl	Trias.
		Conglomerate	Trias.
1172	7	Marl and sandstone	Trias.
1174	0	Red sandstone	Trias.
		Dark shale, at 1180 ft.	Coal measures.
1205	0	Pale sandstone, with plants	Coal measures.
1213	0	Coal measure, duns	Coal measures.
1244	0	Coal measures	Coal measures.
1284	0	Red sandstone and clay	Coal measures.
1308	0	Red sandstone	Coal measures.
1350	0	Argillaceous shale	Coal measures.
		Coal seam	Coal measures.
1368	0	Alternation of Dèvonian and Calcareous from sandstones	Coal measures.
1380	0	Red and green mottled sandstone, with fine-grained bed	Coal measures.
1391	0	Red marls, and sandy beds	Coal measures.
1402	0	Fine-grained sandstone	Coal measures.
1409	0	Red marls, &c.	Coal measures.

With this section it is interesting to compare the red beds, probably Triassic, in the following section:—

Crossness Junction Out-fall Works. New well:—

			Feet.	
		River drift, gravel	39	
		Woolwich beds	47	
137	0	Thanet sands	51	
		Chalk	631	
		Upper Greensand	65	
1003	0	Gault; phosphate at bottom	170	
		Sandstone, very hard	—	Red rocks.
		Grey sand	13	Red rocks.
		Red marl	4	Red rocks.
		Grey sand rock	18	Red rocks.
		Red marl	4	Red rocks.
		Red marl, with blue veins	3	Red rocks.
			1045	

These red beds are absent at Meux's brewery, where beneath 160 feet of gault occurs the well-known *Ammonite interruptus* zone, six inches; limestone, 4 feet 6 inches; lower Greensand, 66 feet, underlaid by mottled red and green argillaceous and micaceous shales of Devonian age, extending from 1070 to 1144 feet from the surface, or 74 feet where the boring was discontinued.

Boring at Messrs. Meux's, Tottenham Court Road:—

	Feet.
Gravel	21
London clay	63½
Woolwich beds	51
Thanet sand	21
Chalk, with flints	347½
Chalk, without flints	305
Upper Greensand	28
Gault	160
Lower greensand	67
Mottled bed, and purple, green, argillaceous and micaceous shales, Devonian fossils	80
	1144

In *Leicestershire* Mr. Plant reports:—

1. That the Lower Lias beds of the Midland districts do not give any constant supply of water. The small quantity found at some places is very hard, and is generally contaminated with sulphuretted hydrogen, arising from the decomposition of the iron pyrites that occur so frequently in these Lower Lias shales.

2. The Rhætic beds and Upper Keuper marls (where the Upper Gypsum bed has been penetrated) yield a good supply of *hard* water, containing, besides carbonate of lime, sulphate of lime to the extent of 100 grains to the imperial gallon. The water is very transparent and very palatable, and is admirably adapted for brewing the fine kinds of beer, when diluted so as to reduce the proportion of sulphate of lime to about forty to fifty grains per gallon.

3. When the Upper Keuper sandstone is penetrated *below the Gypsum* beds—from which it is separated by a considerable thickness of marl (chocolate colour) *impervious to water*—from these sandstones a great supply of water is found, in some places free of lime altogether, either carbonate or sulphate, but in others it is still too hard for the profitable generation of steam. The water in this sandstone depends upon the "outcrop" at various places of the bed, where they have a dip of about 5° to 8° south-east.

4. When the thick beds of red and gray marls lying between the Upper and Lower Keuper sandstone (Waterstones) are bored through, they are generally found quite *dry*, and free from water; but as soon as the Lower Keuper sandstone is penetrated to any depth, *water is always found in great abundance and purity*. The extraordinary supply in this Sandstone is well shown in the Report on the Ellistown Shaft, the beds there delivering (at 300 ft. deep) 60,000 gallons per hour for weeks together, while the shaft was being sunk, and before the tubbing could be put in.

In another instance, these Waterstones yielded a column of pure limpid water from a depth of 670 ft., the column rising 20 ft. above the surface, a total of 690 ft.

Name and Member of Committee asking for information, James Plant.

Name of Individual or Company applied to :—

Ellistown Colliery, Bagworth, Leicestershire.

1. Shafts at colliery. 2. 500 ft. 3. 760 ft.; 13 ft. diameter. 5. 60,000 gallons per hour.

		Feet.
9.	Red marls	200
	Waterstones and Bunter conglomerate	120
	Coal measures	440
		760

12. Large east and west fault. 13. None. 14. None. 15. None.

Rev. P. Hutton, Ratcliffe College, Leicestershire.

1. Quadrangle of Ratcliffe College. 2. 312 ft. 3. 156 ft.; diameter 6 ft.; no bore-hole. 4. Before 8 ft.; after 4 ft.: 6 hours. 5. 240 gallons per hour; 5 hours' continuous pumping will not exhaust it. 6. Not known to vary, to both questions. 7. Not known to vary; above the bed of the river Wreake 8 ft.; bed of ditto, 170 ft. above sea. 8. Carbonate of lime, with free carbonic acid gas; deposits carbonate of lime on standing; hard. 9. Lower Lias and Upper Keuper marls and sandstone. 10. No springs; rain-water only. 11. Entirely kept out. 12. None known. 13. No; well wall quite dry. 14. None known. 15. None known. Well is lined throughout with brickwork; no chamber at bottom; the supply is constant through the year.

Major Campbell, R.E., New Barracks, Glen Parva, Leicestershire.

1. Barrack yard. 2. About 300 ft. 3. Shaft 100 ft. deep; 6 ft. diameter, lined bricks, but not cemented. 4. Bore-hole at bottom of well, 150 ft.; 6 in. diameter. 5. Very little water, and that is thought to be surface drainage. 8. Hard, what there is.

		Feet.
9.	Drift	10
	Lower lias with thin limestone	40
	Rhætic	20
	Chocolate marls	30
	Red marls, chocolate colour	150
	Total	260

Shaft and boring.

11. Into well through want of cemented brickwork.

F. Bates & Sons, Brewers, New Brewery, Humberstone Road, Leicester.

1. Yard of brewery. 2. 220 ft. 3. 62 ft.; 6 ft. diameter; lined with bricks, but not cemented. 4. 30 ft.; falls to 8 ft. by continuous pumping. 5. Fills up quickly after pumping. 6. Not known to vary during the seasons; no variation. 7. No. 8. Carbonate of lime, sulphate of lime (100 grains to gallon), chloride of sodium, sulphate of magnesia. 9. Drift 8 ft.; Upper Keuper marls 52 ft. 10. Yes. 11. No. 12. None. 13. None. 14. None. 15. None.

Gimson & Co., Engineers "New Works," Humberstone Road, Leicester.

1. Yard of works. 2. 212 ft. 3. Well 64 ft.; 6 ft. diameter, lined bricks, but no cement. 4. 30 ft.; reduced to 8 ft. by continuous pumping. 6. Not known. 7. No. 8. Hard; carbonate of lime and sulphate of lime. 9. Drift 6 ft.; Upper Keuper marls 58 ft. 10. Yes. 11. No. 12. None known. 13. No. 14. No. 15. No.

W. Gimson & Sons, Timber Merchants, Church Gate, Leicester.

1. At works. 2. 183 ft. 3. 70 ft. deep; 8½ ft. diameter. 4. 55 ft. before; lowered to 35 ft.; 8 hours, with three 6 in. pumps. 6. Not observed. 7. Not known. 8. Not analysed.

	Feet.
9. Drift, gravel, sand and clay	10
Upper Keuper marls	25
Upper Keuper sandstone	35

10. Yes. 11. No. 12. None. 13. None. 14. None. 15. None.

Evington Coal Company, Lodge Farm, Evington, Leicestershire.

1. Shaft for plaster works. 2. 210 ft. 3. 90 ft.; 7 ft.* diameter, cemented all through with double lining of bricks. 4. Abundant water but not wanted. 9. Drift 4 ft.

	Feet.
Rhætic	20
Upper Keuper marls and gypsum	66

10. Yes. 12. No. 13. No. 14. No. 15. No.

Mr. G. P. Browne, Boring at Newtown Unthank, Leicestershire.

1. Boring at Newtown Unthank, near Desford. 2. 320 ft. 3. 615 ft.; 7 in. bore. 4. Runs over the top, and was first struck at 220 ft. deep.

	Feet.
9. Drift	6
Upper Keuper sand and marls	56
Red marls with sandstone	80
Waterstones	120
Coal measure	353
	615

10. Yes. 12. Yes.

Warwickshire.

Name of Member of Committee asking for information, W. Whitaker.
Name of Individual or Company applied to:—

Leamington Local Board of Health. Trial Boring—Docwra.

	Feet.		Feet.
Made ground	5	Red sandstone	3½
Blue sand	5	„ marl	1½
Sandy red clay	5	„ marl and rock	1½
Red marl and water	6	„ sandstone	2
„ marl	101	„ marl	2
Light blue marl	6	„ sandstone	3
Red marl	2½	„ marl	1½
„ sandstone	3½	„ sandstone	11
Light blue marl	1½	„ marl	2
Red sandstone	12	„ marl and rock	7½
Grey sandstone	26	„ sandstone	4
Red marl	5	„ marl	13
„ sandstone	9	„ sandstone	1
Grey sandstone	3	„ marl	47
Rock	1½	„ sandstone	9
Red rock and gypsum	4½	„ marl	35½?
Blue marl	4		
Red marl	0½		346

* Water so abundant from gypsum beds that, although lined with double row of brick laid in best cement, it forces its way through and stops the working of the mine.

Section of boring for water on the premises of Mr. Knowles in the centre of Nuneaton, 200 or 300 yards N.E. of the boundary fault. Given from recollection by R. E. Sinclair, of Hartshill, Engineer:—

	Yards.
Drift, say	9
Soft red sandstone	20
Alternate light and red sandstone	7
Hartshill stone? or trap?	5

The water was struck under this rock in a few inches of a hard slaty white bed at about 90 yards deep, and rose nearly to the surface.

Mr. Sinclair states that the core brought up from this bed was so much broken up that he is unable to say that it was limestone; but from the hardness of the few inches penetrated he is inclined to believe that this was the case.

Docwra & Sons.

1. Horne's Dyeworks, Coventry. **3.** Shaft 9; bored to 41 ft. from surface. **4.** Water level 4 ft. down.

		Feet
9.	Soil	1
	Clay	3
	Red sand	37
		43

Coventry Works, per Mr.

1. Third well, 25 ft.; shaft —, total 300.

		Feet.		Feet.
9.	Marl	33	Solid rock	7
	Solid rock	2	Marl	32
	Marl	7	Rock and pebble	20
	Solid rock	20	Marl	1
	Marl	10	Solid rock	9
	Solid rock	13	Marl	3
	Marl	2	Solid rock and water	7
	Solid rock	13	Yellow chalk	23
	Marl	14	Marl	9?
	Sand	1	Solid rock	1
	Marl	4	Marl	1
	Solid rock	5	Solid rock	7
	Marl	1	Rock and pebble	1
	Solid rock	2	Marl and pebble	5
	Marl	2	Rock and water	28
	Solid rock	1	Marl and water	4
	Marl	1	Solid rock	18

Docwra & Sons.

1. London and Colonial Brewery, Burton-on-Trent. **3.** Shaft 30 ft., not bored. **4.** 7 ft. down.

		Feet.
9.	Red gravel and sand resting irregularly on red marl	40
	Shale	40
	Red sandstone	17
	Red marl	14
	Shale	3
	Brown marl	2
	Hard shale, with layers of stones	101

Messrs. Docwra & Sons.

1. Brereton Colliery, for Earl of Shrewsbury. **3.** Above 100 shaft; total 980 ft. **9.** Upper part New Red sandstone; lower portion of coal measure.

Name of Member of Committee asking for information, C. E. De Rance.

Name of Individual or Company applied to:—

Mr. Strahan.

1. Eaton Hall, near Chester. **2.** About 14 ft. above highest spring-tide mark (27 ? ft. above Ordnance datum.) **3.** To bottom of rock, 40 ft.; to bottom of bore-hole, 347 ft. **4.** Before pumping sands at 8 ft. from surface. Maximum yield of water = 225 gallons per minute. **7.** Water in well stands at about 6 or 7 ft. above level in the Dee, which is less than 20 yds. distant. **8.** One gallon contains solid residue 63·20 grains.

	Grains.
Volatile matter	2·00
Chlorine	15·20
H_2SO_4	9·36
Lime	11·20
Magnesia	5·98
Oxide of iron	·60
Siliceous matter	·38
Alkalies—	
CO_2	15·84
HNO_3	2·64
	63·20
Total hardness	20°·5
Permanent hardness	15°·0

Free ammonia per gallon, ·001; albuminoid ammonia, ·0021. **9.** B. C. 20 ft. Pebble beds, 227 ft. (Bed of pebbles 5 ft. thick occurred at about 200 ft.) **10.** Probably not.

N.B.—The water was useless for washing or for boilers.

Two breweries in Chester get their water from the Red Sandstone—Seller's (1) and Huxley's (2).

1. In Steller Street.

	Feet.
Boulder Clay B. C.	18
R. Sandstone K.	30

A good spring was struck in soft white rock at this depth; water not very hard; no further particulars to be got.

2. Huxley's Brewery, King Street.

Old well all in pebble beds, 70 to 80 ft.; is pumped dry in 4 to 5 hours. No analysis ever made; water not very hard.

Queen's Park, from Dr. Slotterforth. About 50 feet above O. D.; 36 ft. deep; water stands at 30; deposits iron if left to stand in a vessel.

Rev. A. Grenfell, Neston Local Board.

1. Little Neston Waterworks. **2.** About 140 ft. **3.** Shaft 50 yds.; 9 ft. diameter; 60 yds. **4.** Does not vary. **5.** 105,800 gallons in a day of nine hours. **6.** After a long dry season it lowers about 3 ft. **7.** No. **8.** Chlorine, 2·1 grains per gallon; carbonate of lime, 123 grains per gallon; free ammonia = ·002 parts per million gallons; albuminoid, ·046 parts per million gallons. **9.** Red sandstone and shale cover. **10.** No. **12.** No. **13.** No. **14.** No. **15.** No.

Name of Member of Committee asking for information, W. Whitaker.
Name of Individual or Company applied to :—

Birkenhead.

1. Old Engine, Spring Hill. **6.** 92 ft. from surface when not at work; when level decreased to 130 ft. from surface, yield is 3,614,922 gallons per 48 hours; when 4 ft. lower, two millions in 24 hours; or 285 ft., water in great quantity.

9. New Engine.

	Feet.
Shaft	105
And bore	405 from surface.

Messrs. Docwra & Sons.

1. Cook's Brewery, Birkenhead. **3.** Cell and shaft 58 ft.; not bored.

	Feet.
Made ground	12
Clay	20
Yellow rock	67
Clay	8
Red rock	13
	120

Aspinall's, Birkenhead.

	Feet.
Shaft and cylinder	58; not bored.
Surface soil	7
Sand with water	78
Sand and pebbles	15
Hard clay	10
Red sandstone	34
	144

Messrs. Docwra & Sons.

1. Canada Works, Birkenhead. **3.** Shaft, 45 ft., half filled with concrete; not bored. **6.** Water level, overflows.

	Feet.
9. Surface earth	45
Sand and burrs	8
Blue clay	3
Sand and water	4½
Stony clay	6
Dead sand	7½
Clay	1½
Stony clay	4
Pebble	2
Red sandstone	20
	101½

Lancashire.—A boring of great interest has just been carried to the depth of 1000 ft. at Bootle, near Liverpool, by Messrs. Mather & Platt, for the Corporation of that town.

It was sunk as an experiment to test the water-bearing capabilities of the New Red sandstone; it is perfectly straight from top to bottom, and has the same diameter, 26 in., the whole distance. Cores have been retained at regular intervals, and at every slight change of strata, and have all been examined by your Reporter; a large number of them have also been examined by Mr. Morton.

From the section accompanying the Report it will be seen that more than 900 ft. passed through the Pebble Beds, a thickness at least one-third more than they have been known to attain before; a fact of considerable importance regarding the well-known water-bearing capabilities of this stratum. It will be noticed that thick beds of shaley marl which generally occur at intervals in the Lancashire and Cheshire wells do not occur in this boring; some thin seams are present, but the more marked feature is the boring in the presence of bands of various thicknesses of exceedingly fine-grained and compact sandstone or rag, which alternate with open porous hackly sandstones, holding much water, the rag seams acting as planes of division between the various water horizons. The first of these planes occurs at 268 feet from the surface, from which point down to 368 feet the beds are interstratified with a number of these hard bands, and the character of the rock between is very compact, and probably only moderately porous.

From 368 to 590, part of the series is very porous, where one of the compact belts comes in from 590 to 636 feet, below which a good water-bearing rock comes in, down to 806, where a compact bed of marl comes in, below which to 830 occur many bands of marl and compact rock. From this point downwards, the beds are rather softer in grain, and of an open porous character.

Pebbles first appeared at the depth of 415 feet, and were seen for the last time at a depth of 975 feet, when a decided change in the character of the sandstone occurred, the grain being exceedingly fine; but whether this sandstone is referable to the lower mottled sandstone, or is merely a fine-grained band in the pebble beds, which in that case are more than 1000 feet thick, cannot be determined without sinking the boring to a great depth.

It is a matter of regret that the arbitrary depth of 1000 feet was fixed in the contract, and was now placed at 1000 feet. Had the pebble beds not reached the unprecedented thickness now proved, this smaller depth would have been ample to solve several questions of the greatest scientific interest and practical value, not merely to the district around Liverpool but of national importance—First, as to the water-bearing capabilities of rock at great depth; second, the nature and thickness of the New Red sandstone, and possibly Permian beds, that underlie the pebble beds in that area; third, as to the character and depth of the coal measures under Liverpool. That they exist there, there is little doubt, but to what part of the series they belong can only be determined by boring, and your Committee look forward with much interest to hear that the Water Committee of the Liverpool Town Council have determined to go on with the work discontinued a few days ago on reaching the contract depth of 1000 feet. For should the boring be left at its present depth, it will add to the list of deep borings in the country that have been discontinued at the precise point where the largest amount of information can be obtained.

The level of the water in the new boring is 51 feet from the surface

and maintains its level notwithstanding the continuous pumping carried in the adjoining old well, the water level of which is 50 feet lower.

1. Dallam Lane Forge, Warrington. **2.** About 45 ft. above O. D. **3.** Total depth of well and bore-hole, 887 ft. **5.** Yields 100 gallons per minute with 20-in. vacuum.

8. At 237 ft. from surface	40 grains of salts per gallon.		
345	,,	170	,,
390	,,	300	,,
445	,,	750	,,
500	,,	1246	,,
600	,,	1575	,,
680	,,	3100	,,
756	,,	4000	,,
818	,,	4500	,,

These figures represent number of grains per gallon produced by nitrate of silver, *i.e.*, chlorides alone. Water has a strong briny taste.

	Feet.
9. Drift, chiefly B C., about	30
Red and pale yellow rock, soft	350
Red and white ditto, with thicker sides	2
Micaceous sandstone	3
Pale red and yellow ditto, with a bed of weak red marl	57
Red sandstone, with white bands and 2 ft. of marl	190
	602

Name of Member of Committee asking for information, Professor Hull.

Name of Individual or Company applied to—

Messrs. Worrall.

1. Dyework, Old Garrat. **3.** 109 yards. **5.** 384,480. **9.** New Red sandstone.

Mr. Boddington.

1. Brewery, Strangways. **5.** 55,840. **9.** New Red sandstone.

Messrs. Bury's Dyeworks.

1. Salford. **3.** Wells and bore-hole 100 yards. **5.** 353,240 gallons, and 66,240 at Messrs. Moseley's Dyeworks, a quarter of a mile off; an engine pumps 1,500,000 gallons per day.

Mr. Charlton.

1. Charlton's Work, Salford, 150 yards from Boddington's Brewery. **3.** 70 ft. with bore-holes. **5.** 348,000 in 16 hours.

1. Mr. Smith's (late Joule's) Brewery, Salford. **3.** 206 yards, with chamber in New Red sandstone. **5.** Two pumps can be kept at work for forty-eight hours, yielding 137,000 gallons. **7.** Water-level is that of river Irwell.

	Yards.
9. New Red sandstone, about	156
Marls with limestone	40
Rock and clay alternating with hard sandstone with water	10

Mr. John Wood.

1. Works, Medlock Vale. **3.** Bore-hole, 761 ft. **7.** Water was met with in the Lower Permian sandstone, and flowed over the surface.

		Ft.	in.
9.	Alluvial gravel	26	0
	New Red sandstone	23	0
	Permian marls, with bands of gypsum and limestone	246	3
	Lower Permian sandstone	375	11
	Coal	90	0
		761	2

1. Collyhurst Sand Delf. **5.** Exhausted after 12 hours' pumping. **8.** Water hard, but transparent. **9.** Lower Permian sandstone.

Mr. John Knowles.

1. Broughton Road Paperworks. **5.** 100 gallons per minute.

		Feet.
9.	1. Stiff, close hard stuff, probably drift and New Red sandstone	240
	2. Red loam, with mixture of clay and shale (probably Permian sandstone)	150
	3. Hard bands (probably coal measures)	120
		720

Messrs. Worrall's Works.

1. Ordsal. **3.** Well, and bore 460 ft. Pumped for 12 months, yielding 717,120 per day. **8.** Water brackish, probably due to this well being on the dip of all the others, and the ponding up of water causing impregnation of the water with salt.

Name of Member of Committee asking for information, Mr. De Rance.
Name of Individual or Company applied to—

Mr. Binney, F.R.S.

1. Messrs. Hoyle's Works, Mayfield.

		Ft.	in.
9.	New Red sandstone	143	4
	Permian marls with bands of limestone	153	9
	Lower Permian sandstone	59	4

Particulars of Whiston Pumping Station, given by Mr. Stooke.

Works occupy one statute acre; 50 in. cylinder single power expansion engine; 9 ft. stroke; capable of delivering 1,000,000 gallons.

1870.—Two wells, 9 ft., diameter, 45 yds.; then carried on as one well; at 59 yards, yields 200,000 gallons per 24 hours; at 75 yards (= 25 ft. O.D.), yields 400,000 gallons per hour; bore-hole, 18 ft. to 104 yards; fault, 2 + to 1; average yield, 320,000 gallons.

1872.—Tunnel · Eastwood, 240 yards in length to boundary of township; fissures laid open; water, 430,000 gallons; at 87 yards strong spring forced back the rock and endangered the men's lives; 500,000 gallons pumped out daily, and the water rose 43 yards during the 24 hours.

7 do. supplies 640,000 gallons per day; auxiliary well at end of tunnel at 53 yards yields 380,000 in 24 hours; at 75 yards yields 470,000 in 24 hours; combined wells yield 970,000 gallons in 24 hours.

Sept. 1875.—Average daily yield, 1,000,000 gallons; connection of two wells by tunnel; borehole for auxiliary well less than 240 ft.

1876.—Mean daily supply, 868,000 gallons; latter-half of the year, mean daily delivery was 938,000 gallons.

The Secretary of your Committee has to thank Messrs. Mather and Platt for permission to examine the cores brought up in the deep boring they are now executing for the Liverpool Corporation, near Bootle, the whole of which is carried out in Red sandstone of Pebble-Bed age down to a depth of 1042 ft., where the Lower Mottled Sandstone makes its appearance. The following gives a description of any special character of bed passed through, intermediate spaces being occupied by ordinary grained and coloured sandstone:—

Ft.	in.	
29	0	Very fine-grained sandstone.
31	6	Lighter fawn coloured, partially porous.
69	0	Marl pockets, in red sandstone.
79	0	Very fine-grained red sandstone.
97	0	Dark shaley sandstone, patches of mica.
113	0	Hackly sandstone, small marl pockets.
144	0	Very fine-grained micaceous sandstone, 6 in. thick.
224	0	Very hard fine-grained sandstone, small pockets of marl, 16 ft. 11 in.
237	0	Hackly sandstone.
268	0	Grey marly parting, resembling those in the water stone.
279	0	Pocket of red marl.
283	0	Red marl, 2 in.; marl pebble, 2 in. long.
290	0	Very fine-grained red sandstone, evenly bedded, 12 ft.
303	0	Very compact grey sandstone.
303	6	Fine-grained sandstone.
319	0	Compact white sandstone.
327	9	Compact grey sandstone.
330	0	Hackly, red marl pockets.
335	0	Hard compact grey micaceous sandstone; dip 4 in.
339	0	Dull red finely-grained red sandstone.
351	0	Grey rag, black mica, green marl, 6 in.
361–4	0	Very fine-grained red sandstone, bedding horizontal.
366	0	Shaley and sandy marl, 6 in.
371	0	Very fine-grained dull red sandstone, white mica.
415	0	Hard compact grey sandstone, 2 in.
415–2	0	Compact red sandstone, *white quartz pebbles.*
437–6	0	Grey sandy marl.
453	0	Many pebbles of quartz and grit.
455	0	White micaceous rag, 2 in.
468	0	Hard, coarse, hackly-grained sandstone with pebbles.
470	0	Grey sandy parting, 3 in.
470	3	Compact fine-grained sandstone.
497	0	Hackly red sandstone, 27 ft. thick.
500	0	Hackly red sandstone, dark sandstone pebbles.
512	0	Red sandstone, dark grit pebbles.
514	0	Compact grey micaceous rag.
514–35	0	Hard fine-grained sandstone, no pebbles.
535–73	0	Hard, rather fine-grained, with pebbles.
573	6	Compact grey, fine-grained rag, 12 in.
587	0	Very fine-grained sandstone, no pebbles.
590	0	Hard sandstone, many pebbles.
594	0	Compact band, 2 in.
599	0	Compact band, 2 in.
611	0	Hard strings.
621	0	Grey micaceous parting, 3 in.
624	0	6 ft. 9 in. of pebbly sandstone.
634	0	Very compact marly sandstone, 2 ft.
694	0	Compact grey sandstone, 4 in.
740	0	Grey, very compact rag, 4 in.

Ft.	in.	
749	0	Compact grey rag, 3 in.
758	0	Ditto, 4½ in.
774	0	Open hackly rock.
803	0	Open hackly sandstone pebbles.
803	0	Very hackly sandstone pebbles, 21 ft.
806-12	0	Marly bed, 2 ft. 6 in., fine-grained hard shaley sandstone.
814	6	Rough hackly sandstone.
826	0	Rag parting, 6 in.
830	0	Sandy marl, 2 in.
842	0	Conglomerate.
855	0	Grey rag, 1½ in.
872	9	Finely bedded rag, 6 in.
888	0	Parting, 6 in.
890	0	Parting, 3 in.
893	0	Compact sandstone, pebble.
897	7	½ in. purple shale.
907	0	Grey rock, 3 in.
912	0	Purple marl, 1 in.
917	0	Rather open sandstone pebbles.
950-69	0	Fine-grained red sandstone, full of water.
956	0	Many pebbles.
964-2	0	Red sandstone, pebble (sample).
966	6	Open pebbly sandstone, 10 ft. 6 in.
966	9	Rather open rock, few pebbles.
968	0	Rather hard white band, 1 ft. 6 in.
969	6	Hackly pebbly sandstone, small flakes of white mica, 5 ft. 6 in.
975	0	Fine-grained red, thin beds, *one pebble*, little mica.
		Hard rag and grey marl, 2 in.
		Softer fine-grained red sandstone, very minute specks of mica.
982	0	Soft sandstone.
990	0	Soft sandstone, indistinct ripple markings.
994	0	Fine sandstone.
995	0	Red sandstone (specimen).
1000	0	Fine sandstone.
1003	0	Red soft sandstone.
1007	0	Red sandstone.
1007	6	White hard sandstone, 6 in.
1010	0	Red sandstone, mica planes.
1013	0	Red open sandstone.
1015	0	1 in. to 3 in. red marl.
1016	3	Shaley hard marl, 2 in.
1016	5	Rag and clunch, 7 in.
1017	0	Open sandstone, marl pebble.
1019	0	Open sandstone, pebbles.
1022	0	Open sandstone, 8 ft. 3 in.
1025	3	Open white sandstone.
1026	3	Hard red sandstone.
1028	9	White open sandstone.
1029	0	Open red sandstone.
1032	0	Open red sandstone, much water.
1035	0	Open red sandstone, flat bedding, 9 ft. 7 in.
1038	0	White sandstone, green marl pebble, red micaceous parting.
1039	0	Open fine-grained red sandstone.
1042	0	Open red sandstone, round grains.
1045	0	Open red sandstone, little mica.
1048	0	Fine-grained red sandstone.
1051	0	Red sandstone, fine and coarse.
1054	0	Fine-grained red sandstone.

Ft.	in.	
1057	0	Fine-grained soft red sandstone, 31 ft.
1060	0	Round-grained soft red sandstone.
1063	0	Red sandstone.
1066	0	Rather hard red sandstone.
1069	0	Soft red sandstone.
1072	0	Coarse sandstone.
1075	0	Red sandstone, very soft.

Appendix to Triassic Report.—Experiments on the Filtration of Sea Water through Triassic Sandstone. By Mr. ISAAC ROBERTS.

In the town of Liverpool several million gallons of water are pumped daily out of wells sunk in the Pebble Beds of the Bunter sandstones.

The whole area from which this quantity is withdrawn is covered by pavements, buildings, and a thick bed of boulder clay, so that it is not possible for much, if any, of this large daily supply of water, to percolate from the surface into the sandstone. Nor are there within the sandstone rocks of this neighbourhood open fissures or channels through which the water could freely pass from distant sources into the wells; nor are there subterranean reservoirs of water (leakages from pipes and sewers excepted) from which the supply could be drawn. Where, then, does the water come from?

In a paper which I read before the Geological Society of Liverpool in 1869, I suggested that most of it must flow from the Liverpool Docks and the River Mersey by passing through the mass of the rock; and that the sandstone rock must filter, or chemically neutralize the salts held in solution in sea water. In the paper referred to, I gave analyses of the water drawn from several wells in Liverpool and the neighbourhood, to show that there is a gradual constant accumulation of salts in the water obtained from all the wells respectively. I will here give one example, which shall be typical of the rest. The well is situated in Rainford Square, distant 500 yards from the nearest dock, and 800 yards from the River Mersey. The analyses are given in tabular form, to facilitate comparisons:—

WATER FROM THE WELL, RAINFORD SQUARE.

Salts in Solution	Grains per Gallon			In the River Mersey
	In 1867	In 1871	In 1878	
Chloride of sodium	—	138·44	208·64	
Do. magnesium	—	49·01	63·49	
Do. calcium	—	51·45	69·26	
Total chlorides	—	238·90	341·39	1334·9
Sulphate of lime	—	26·55	37·38	
Carbonate of magnesia	—	2·22	1·16	
Do. lime	—	8·68	6·58	
Nitrate of soda	—	—	2·15	
Total solids	231·00	276·35	388·66	1505·0

Between the years 1867 and 1871 the *salts* had increased 19·63 per cent., and between 1871 and 1878 they had further increased 40·64 per cent. The rate of increase between 1867 and 1871 was 4 91 per cent. per annum, and the rate between 1871 and 1878 was 5·81 per cent. per annum. The difference is to be accounted for by the larger quantity of water per day that has been pumped out of the well. Since the year 1871, 295,200 gallons daily have been taken out of the well, which is equal to 88½ million gallons per annum.

The well had been in use for many years prior to 1867, but in that year it was deepened, and a bore-hole made to increase the supply of water.

The inference drawn from this, and like results obtained elsewhere, was that the Bunter sandstone rock filtered salts out of sea water.

In the months of March, April, and May this year, I submitted the inference to the test of the experiment now to be described.

I selected four cubes of Bunter sandstone from the pebble beds in a quarry in Everton. Each cube measured accurately 12 in. by 12 in., by 13 in. high. The top surface of each cube was dished out 9 in. by 9 in., by 1 in. in depth, to form a receptacle into which water could be poured.

Three of the cubes were thoroughly dried in air, and placed one above the other in a frame, so that the water poured on the dished part of the upper one would, after passing through it, drop into the dished top of the second cube, and after passing through the second would drop on to the third, and after passing through the third cube, would drop into a bottle placed underneath to receive the final filtrate.

The first trial showed the water followed the planes of stratification before passing through the whole thickness of the cube. That cube was therefore rejected in the experiment. The second trial showed that the dished part of the cube was cut on the edge of the planes of stratification, and there was also some evaporation from the sides. The water passed through this cube in eighteen hours. This cube was also rejected on account of the defects which I have stated.

In order to prevent leakage through the sides and evaporation, I coated four of the sides of the two remaining cubes with black varnish, and closely covered them and the frame holding them with oil-cloth; by these means the water passed through their mass under conditions favourable to give accurate results. I also cut three cubes measuring 1½ in. on each side from the same stones (exhibited at the Dublin meeting) to ascertain the capacity of the sandstone for storing water, the storage space being the aggregate of the microscopic interstices which exist between the grains of quartz, of which the sandstone is composed, and also of the faults and fractures.

The mean result obtained from the three cubes was that each cubic foot of sandstone would store 0·733 gallon of water.

Let us now consider the experiment on filtration.

I took from the River Mersey off the Rockferry slip, at half tide ebb, fifteen gallons of water, and allowed the muddiness to subside before filtering through the stone. A portion of the water was then carefully run in small quantities into the dished part of the first cube, until it began to drop from the bottom; and when two fluid ounces had passed through, I carefully analysed the quantity of the chlorides left in the filtrate, and found that 80·8 per cent. had been removed by the filtration.

The water was then allowed to filter through and drop into the second cube until it passed without any change from the condition of sea water. The second cube, it will be observed, was partially saturated with the filtrate from the first cube, and sea water was added continuously, till it began to drop from the bottom of the second cube, when it was received, into bottles and carefully analysed with the results given in the following table, namely:—

	Quantity in fluid ounces	Percentage of Chlorides removed
1st filtrate	$3\frac{1}{2}$	80·8
2nd do.	4	76·6
3rd do.	4	71·27
4th do.	4	64·89
5th do.	4	57·44
6th do.	4	53·19
7th do.	4	46 8
8th do.	8	41·68
9th do.	8	31·9
10th do.	8	25·53
11th do.	8	21·27
12th do.	8	10·63
13th do.	8	10·63
14th do.	18	8 51
	$93\frac{1}{2}$	

These filtrates are obtained from two cubic feet of sandstone.

The last drops of the fourteenth filtrate were of the same composition as the sea water, and therefore the filtering power of the stones was exhausted.

In the analyses here given, I dealt only with the *chlorides*, these being by far the larger and most characteristic constituents of sea water, as will be seen by the following analysis of the sea water used in the experiments, namely:—Total solids in one gallon=1505 grains, of which 1334·9 grains are chlorides of sodium, magnesium, and calcium.

Mr. A. Norman Tate, F.C.S., analysed the first, fifth, and thirteenth filtrates, and his analyses agreed to within less than one per cent. with my own as given in the table above, thus proving their substantial accuracy. It follows then that $93\frac{1}{2}$ fluid ounces of sea water passed through two cubic feet of sandstone before they became inoperative as filters, and nearly the whole of the salts were removed from the water that first passed through.

Applying this knowledge to account for the water withdrawn from the wells in Liverpool, we should proceed as follows:—The rain water which was stored in the cavities of the rock would be tapped by the wells and bore holes, and pumping would cause a current under great frictional resistance to flow towards the well as a centre from all directions in the surrounding rock. The flowing water, owing to the frictional resistance and capillary attraction of the rock, would assume the form of an irregular inverted cone, the apex of which would be the bottom of the suction pipe of the pump, and the base would be the stationary water level towards the surface of the rock. If the area which forms the base of the water cone is pervious all over to rain water, and remains uncovered, the rainfall would be partly absorbed by the rock, and so keep an equilibrium

with the quantity pumped. If this quantity should be large, the bottom of the suction pipe, or, in other words, the apex of the water cone, would have to be carried down until the base of the water cone is enlarged to an area sufficient to supply the requirements of the pump. If that area is partly covered with anything which is impervious, the base of the water cone would extend wider and wider till it reached some source of water, and then, like blotting paper, the exhausted rock would absorb it and pass any excess to the flowing stream which leads to the pump.

In Liverpool there are several wells within one mile of the docks and river Mersey, yielding daily several million gallons of water. The yield has been continuous for many years. The water has become more brackish each year, some of the wells yield water half as brackish as sea water, but it has always been a mystery where water less salt than sea water percolates so largely into them.

The expriments just described will, I think, dispel the mystery and give data for calculating the quantity of water freed from salts any given area and depth of similar sandstone rock would filter.

The next question I wished to decide was—Is the filtration through the sandstone a mechanical or a chemical process? I will give the answer as follows:—

One of the cubes of stone which I had used as a filter in the first experiment was allowed to dry in air for a month, and then I poured spring water into the dished part, as I had done with the sea water. Following are the results obtained, and given here in tabular form:—

	Quantity of filtrate in fluid ounces	Percentage of the Chlorides washed out
1st filtrate	24	157·77 } 101 fluid ounces.
2nd do.	45	122·22 }
3rd do.	32	102·22 }
4th do.	40	55·55
5th do.	40	4·44
6th do.	12	2·22
	92	

Taking sea water at 100 as the standard for comparison, we see that in the first filtrate of 24 fluid ounces there was an increase of 57·77 of the *chlorides*, and the third filtrate shows that it required 101 fluid ounces of water to reduce the salts which had accumulated in the pores of the stone cube during the filtration of the sea water to the standard of the original sea water. The sixth filtrate shows that 92 fluid ounces additional of spring water washed out all the remaining chlorides which the cube had taken out of the sea water. The last drops of the sixth filtrate only showed a trace of salts remaining.

It appears, therefore, that the filtering action is purely mechanical or molecular, and not the result of any chemical action by the rock upon sea water.

If I may hazard an opinion in a report intended to be free from assumptions, I would suggest, as a probable explanation of the results obtained, that the capillary attraction of the grains of sand of which the rock mass is composed is more powerful for the sodium, calcium, and magnesium chlorides, than it is for the water of solution. These are, there-

fore, retained in the stone, whilst the water of solution filters out. But if excess of pure water be allowed to run through the stone, the salts are again taken in solution and carried away by the water. I simply offer this as an hypothesis which may explain the results obtained in the experiments.

Report on the Jurassic Rocks.

The geology of the oolitic districts has determined, as pointed out many years ago by your chairman, " the sites of most of the villages. Thus along the valley of the Evenlode villages are planted wherever there are copious springs combined with a dry situation, circumstances generally to be found in the small lateral valleys which are excavated in the oolite and lias, and in these most of the villages are grouped. In other parts of the district similar advantages have determined the sites of Enstone, Kiddington, Glympton, Wotton, Woodstock, Bladon, Steeple Barton, &c. Some of these villages are perhaps as old as the Norman Conquest, and have not altered much in size through several centuries." *

At Trowbridge, a well was sunk to a depth of 160 ft., and an 18 in. bore-hole a further 40 ft.; a salt water spring was met with in the shaft, but the water is still brackish, yielding no less than 6 lbs. of common salt from 1,000 gallons of water, 3 oz. being the usual average, the hardness being 57·1 parts per 100,000.

This quantity of salt is of course exceptional; there are no records of a good and plentiful supply being obtained from the Lias. In those which yield a large quantity, the water is invariably derived from overlying porous gravel.

At the base of the Inferior Oolites powerful springs are thrown out, and flow in streams and rivulets over the Lias plain at their base. The commissioner gives several examples of clay-land parishes of this character in the valley of the Severn, which at present do not receive their water supply until it has been hopelessly contaminated; with one marked exception, that of Coaley, near Frocester.

The common lands of this parish were enclosed under the superintendence of a Deputy Commissioner of the Enclosure Office. The frontages to the highways were fenced in, and the footpaths to the brooks closed; the several landowners who benefited by the enclosure in return laid a two inch iron pipe from the spring through every hamlet in the parish, and built a small reservoir at the spring head.

That landowners should be able to charge their property as a land improvement with the cost of such proceedings as may be necessary for the provision of pure water to villages and hamlets, is a matter of great importance, recommended as it is by Her Majesty's Enclosure Commission, and supported by the Rivers Pollution Commission.

The well at Witney is at Messrs. Clinch and Co's. Brewery, and is 65 ft. deep. The water, which through the depth of the well has been tolerably filtered, is derived from the upper part of the Great Oolites. None of the wells of this district, however, supply water as pure as that flowing past the town in the Windrush. In this district a good supply of water might be obtained by carefully constructed wells of sufficient depth.

* Professor Hull, F.R.S., Mem. Geol. Surv. Exp., Sheet 45 S.W.

At Bicester, an artesian boring is described by the Geological Survey as reaching a good spring at the base of the Great Oolite, 244 ft. from the surface.

It is an interesting fact, that three years before Sir Hugh Myddleton bought the Hertfordshire chalk springs by the New River to London, one Otho Nicholson, of Christ Church, Oxford, brought the water of a small spring to Carfax Cross in that city, issuing from the base of the Coralline Oolite, on the hills above North Hincksey, a distance of two miles across the valley of the Isis. The spring still yields 10,000 gallons daily but the supply was cut off and the cross removed in 1787.

The following are some of the more important springs in the Oolite district, about Oxford, given by Messrs. Pole and Bravender in their evidence before the Royal Rivers and Pollution Commissions.

	Gallons.
Ablington	2,000,000
Ampney, near Cirencester	12,000,000
Bibury	10,000,000
Bourton, Eyeford, and Donnington, near Stow-on-the-Wold	25,000,000
Boxwell, near Cricklade	1,200,000
Ewen	1,000,000
Seven Springs, near Northleach	500,000
Seven Wells	2,000,000
Syreford, near Cheltenham	4,000,000

Professor Prestwich gives the following abstract of the beds passed through, and compares them with the thicknesses of the oolitic strata of the neighbourhood, estimated by Professors Phillips, Hull, and Green.

Thicknesses of Strata at Wytham boring.

Beds.	Oxford Clay:—	Ft.	in.
No. 25		9	6
„ 26–32		38	0
„ 33–50		131	6
„ 51–55		14	6
	Wanting:—		
„ 56–59		170	6 (+)

At Charbury, Woodstock, and Enslow Bridge.

	Feet.	ft.	in.
Oxford Clay			
Cornbrash	9		
Forest Marble	25		
Great Oolite, Upper	60	179	6
„ „ Lower	70		
Inferior Oolite	15		
Upper Lias	8		
Marlstone and Lower Lias	400?		

The boring was followed by another a few years later, in the hope of obtaining water, at St. Clement's, but unfortunately a salt spring was reached at 420 ft., which is still flowing. The beds passed through, according to Professor Prestwich, were probably the Oxford Clay and Great Oolite, and the analysis of the water from the artesian well at St. Clement's, Oxford, by Mr. W. F. Donkin, February, 1876, was published by Professor Prestwich.

Sodium chloride	1069·0
Sodium sulphate	510·0
Calcium sulphate	193·1
Calcium carbonate	10·9
Magnesium chloride	38·9
Silica	1·8
Ammonia	0·1
	1824·7 in 100,000 parts.

With traces of potash, iron and alumina.

Weight of total solids, dried at 170° C., 1831–5.
Specific gravity of the water at 9° C., 1·01462.

Section of Wytham Boring.

Presented by the Earl of Abingdon to the Oxford Museum in 1849, and published in Phillips' 'Geology of Oxford,' p. 296.

	Ft.	in.
1. Loamy ground	12	0
2. Quicksand and water	3	0
3. Blue clunch	68	6
4. Light clunch	1	6
5. Blue clunch	28	6
6. Clunch bines	4	6
7. Blue clunch	29	0
8. Clunch bines	2	0
9. Blue clunch	28	0
10. Brown clunch	3	0
11. Mingled ground	11	6
12. Strong grey rock	1	0
13. Grey clunch	2	0
14. Brown clunch	1	6
15. Mingled ground	17	0
16. Blue clunch bines	6	0
17. Mingled ground	4	0
18. Blue clunch	17	6
19. Mingled ground	9	6
20. Blue clunch	5	0
21. Dark blue rock	3	6
22. Dark parting clunch	0	6
23. Dark blue rock	2	6
24. Dark clunch	11	6
25. Strong blue rock (Cornbrash)	10	6
26. Dark parting clunch	1	0
27. Strong blue rock	5	6
28. Strong parting clunch	0	6
29. Blue rock	1	6

	Ft.	in.	
30. Clunch and clunch bines	6	0	
31. Grey rock	18	0	
32. Dark parting clunch	0	6	
33. Light rock	30	3	Great Oolite. (33–50)
34. Light parting clunch bines	0	9	
35. Light rock	5	0	
36. Very dark parting	2	0	
37. Grey rock	1	4	
38. Dark parting	0	8	
39. Clunch bines	7	6	
40. Grey rock	3	0	
41. Dark parting	1	6	
42. Grey rock	2	6	
43. Blue bines	2	0	
44. Mingled ground	3	0	
45. Blue rock	9	0	
46. Dark ground	1	6	
47. Mingled ground	7	6	
48. Light rock	16	6	
49. Black bat.	2	0	
50. Rock	35	6	
51. Mingled ground (Inferior Oolite)	11	7	
52–5. Mingled ground (Inferior Oolite)	3	0	
56. Ironstone (marlstone)	0	4	
57–58. Clunch in ironstone (marlstone)	132	0	
59. Dark clunch (marlstone)	2	0	

"The boring was carried to the depth of 633 ft., the strata the same as that at 596 ft."—C. Webb.

The boring was made in 1829.

To exclude sources of contamination, the water is remarkably free from organic impurity, the amount in some cases being as low as ·047 part in 100,000, and ·033 grain per gallon, at Scarborough well, and

·012 part in 100,000, or ·008 grain per gallon, in Garner's spring, Northampton. In fact, "unpolluted spring water from the Oolites is unsurpassed in its comparative freedom from all kinds of organic impurity."

The oolitic rocks are very porous, absorbing and holding enormous volumes of water, which are again delivered as springs usually of great size. As water-bearing rocks are equal, if not superior, for the purification and storage of water, the oolitic rocks are equal, if not superior, to the chalk itself. But this vast store of magnificent water is rarely used by communities until it is hopelessly polluted. The analyses show that great care should be exercised to cut off surface contamination in deep wells, and that shallow wells are absolutely unsafe.

An area of no less than 6671 square miles is occupied by the oolitic rocks of England, with an annual average absorption of not less than 10 in. of rainfall, a figure probably much below the real average.

Professor Hull describes the two chief sources of springs among the Cotteswolds, at the base of the Great Oolite, or Stonefield slate, at its junction with the Fuller's Earth, and at the junction of the Upper Lias clay with the overlying sands. To the latter horizon belong the seven springs forming the source of the Thames. Smaller springs issue in the district at the base of the Lias marlstones and the upper surfaces of forest marble clays.

Gloucester is partially supplied by springs in the flanks of Robin's Wood Hill, thrown out by the Lias, which, with the surface drainage of 1,500 acres, are collected in a reservoir holding 62,000,000 gallons. The water is nineteen and a half degrees of hardness, which could be reduced to three and a half by Clark's process.

Three springs at Cheltenham are collected along the flanks of the hills in bricked wells, and conveyed to the reservoirs at Hewlett's Hill and Leckhampton, together holding 35,000,000 gallons. Above 300,000 gallons are daily delivered. The water is much softer than most oolitic springs, the hardness being only 15·0, of which 6·0 is permanent; that of Haydon, near Cheltenham, is no less than 45·7, of which 13·4 is permanent.

The saline springs of Cheltenham rise, according to Professor Hull, like the water in artesian borings, along planes or fissures in the Lower Lias, and are probably from water percolating through salt-bearing Keuper, which outcrops at high elevations, as first explained by Sir Roderick Murchison.

Description	Temperature Centigrade	Total Solid Impurity	Organic Carbon	Organic Nitrogen	Ammonia	Nitrogen as Nitrates and Nitrites	Total combined Nitrogen	Previous Animal contamination	Chlorine	Hardness: Temporary	Hardness: Permanent	Hardness: Total	Remarks
Bath, Hetling Thermal Spring	44°·4	240·52	·161	·036	·029	·439	·499	43·10	26·50	22·0	82·8	104·8	Clear
Bath, King's Bath, Thermal Spring	42·2	245·40	·190	·019	·039	·447	·491	44·00	26·67	22·0	82·8	104·8	Clear

Bath is supplied with water by no less than eighteen private companies; the chief quantity of water is derived from springs off the Upper Lias. The water derived from the Beacon springs is described as the best by the Royal Commissioners; but even this is not quite satisfactory, and it is a remarkable fact, pointed out by them, that the thermal springs of Bath, like the cold water, contain a large amount of organic impurity (see table, p. 404).

These waters have been tapped in a well at Kingsmead Street, at the junction of the Keuper and Penarth beds. They were believed by William Smith, and later by Sir Charles Lyell, to rise from subjacent carboniferous rocks at a great depth. They give off, according to Dr. Daubeny, a daily quantity of 250 cubic ft. of nitrogen gas as well as carbonic acid gas. Lithium, strontium, and copper have been determined in their waters by Dr. Roscoe, and the following salts were found by Messrs. G. Merck and Galloway in an imperial gallon:—

Carbonate of lime	8·820
" magnesia	0·329
" iron	1·071
Sulphate of lime	80·052
" potassa	4·641
" sodium	19·229
Chloride of sodium	12·642
" magnesium	14·581
Silicic acid	2·982

The following well sections, collected by Mr. Bristow, F.R.S., in the Bath district will be found useful for thicknesses:—

1. America Buildings, near Lansdown.

	Feet.
Fuller's earth	20
Inferior Oolite	30
Midford sand	100
Blue clay (Lias)	24
	174

Water obtained.

2. Beckford's Tower.

	Feet.
Great Oolite	30
Fuller's earth	70
Sand	—
	100

3. Claverton Down.

	Feet.
(Great Oolite). Bastard freestone	80
(Fuller's earth). Clay	20
	100

Water obtained.

4. Holloway Brewery, above the Old Bridge.

	Feet.
Midford sands. Rotten sands	30
Lias. Blue clay with whinstone bands	200
	230

Well abandoned, no water.

5. Holloway Hill (top of).

	Feet.
Inferior Oolite. Loose rock	30
Midford sand	50
	80

Water in great abundance. Clay not reached.

6. Bear Inn, Holloway.

	Feet.
Loam and brash	10
Midford sand	30
Lias. Blue Clay	—
	40

7. Prior Park.

		Feet.
Trace of fuller's earth ?		
Great Oolite	Loose rock	20
	Oolite	20
	Hard freestone	20
Fuller's earth ?	Clay	40
		100

Water obtained.

8. Macaulay Buildings, above Widcomb Church.

	Feet.
Inferior oolite	40
Midford sand	100
Lias (blue clay)	34
A spring met with	174

A very useful table, giving the thicknesses of Triassic and Jurassic strata of the Bristol and Bath area, is given by Mr Bristow in his evidence to the Royal Coal Commission, which has been added to by Mr. H. B. Woodward, and reprinted pp. 408–410.

The Great Oolite, at Bath, consists of the following series :—

		Feet.
A. Upper Rags	1. Course shelly limestone	20 to 55
	2. Rather fine grained oolite	
	3. Tough brown limestone	
B. Fine freestone		10 to 30
C. Lower Rags.	Course shelly limestone	10 to 40

The good freestone is very soft, when first obtained, containing much moisture, amounting sometimes, it is said, to one gallon of water per cubic foot.

The Bradford clay, a local thickening of the clayey beds of the overlying Forest marble, reaches its greatest thickness at Farleigh, where it reaches forty to sixty feet. The Forest marble around Bath is a hundred feet thick, in the Cotteswolds not more than fifty.

The Cornbrash-ruffly limestones reach a thickness of more than forty feet, and are overlaid by 300 to 400 feet of Oxford clay.

The coal rag only appears in the Bristol area, as Longleat Park, it underlies the Kimmeridge, which reaches a thickness of sixty-five feet at Maiden Bradley.

In the oolitic outcrop, ranging between Crewkerne, through Bath to Wotton-under-Edge, described by Mr. H. B. W. Woodward, the coal rag, when present in water bearing the Oxford clay, form the impermeable layer, as does also the Cornbrash and the upper sandy beds of the Forest marble, which are held up by the clayey beds beneath.

The outcrop of the Cornbrash, between Witham Friary, South Brewham, and Hardway to Wincanton, is marked by a line of villages, due, as pointed by Professor Buckman, "not only to the fertility of the Cornbrash, but to the resemblance that this porous rock, resting on the impervious Forest marble, is a collecting ground for water, which is kept up by the latter rock."

The labours of Professor Judd, in Lincolnshire, enable the following classification of the bed at the base of the oolites to be adopted :—

	Equivalents.
Cornbrash	Cornbrash.
Gr. Oolite clays and limestones	Gr. Oolite.
Upper Estuarian series	Stonesfield slate.
Lincolnshire oolite with Collyweston slate at its base	Inferior white.
Northampton sands with Lower Estuarian series	(Lower Freestones).

The Lincolnshire oolites are absent in the eastern and southern portions of the Midland district, and the Upper Extension series which form the base of the great oolite series rest directly upon an *eroded* and denuded surface of the Northampton sands, when the Lincolnshire oolites are present, however, they, too, are found to be eroded, proving them, like the Northampton sand, to be of inferior oolite age.

The basement beds of the Northampton sands rest in Rutland, and South Lincoln, on an eroded surface of Upper Lias clay, and generally consisting of ironstone oolitic rock, forming a bold escarpment, "The Cliff," stretching away for ninety miles through Lincolnshire to Yorkshire, at the base of which copious springs arise, at the junction of the lias, the beautiful Eleanor Cross at Geddington is over one. Springs are thrown out in a similar situation at Pipwell, where there is the remains of an old reservoir.

At Blatherwyche Park Inlier, one well sunk to the Northampton Sandrock yielded a good supply, but another was strongly impregnated with sulphurated hydrogen.

At Collyweston, a number of wells have been sunk through the thick beds of the Lincolnshire oolites, into the 'red-rock,' or ironstone, which itself supplies the large quantities of water used in the working of the 'Slate pits.'

To this horizon are due the springs of Wolthorpe, collected in a reservoir for the supply of Stamford.

Very copious springs are also given off by the base of the ironstone of Easton, used for the supply of that village.

Near Stamford, a futile attempt to find coal was made by the late

		Dolomatic Conglomerata	Red Marl and Sandstone	Penath Beds	Lower Lias	Middle Lias	Upper Lias	Midford Sands	Inferior Oolite	Fuller's Earth	Gr. Oolite
35	Almondsbury (between Winterbourn and)	100 to 200									
,,	Ashton Vale Pit	63									
19	Ashwick	45–90									
35	Aust	110–120		35	170–260						
19	Bath	— †	—	39 †			....	100	30	150	60 *
,,	Batheaston	24	30	34	247						
35	Bedminster	100									
19	Bishop's Sutton New Pit	4 *	120								
35	Brislington	60 to 180									
31	Bristol	....	300†								
19	Bruton (Scorle Hill, Batcombe)	....	....	....	....	21		66	55	179	
,,	Bruton Westcombe	....	....	....	....	70					
35	Cold Ashton.........................	....	....	....	....	....	....	....	....	....	40
19	Combe Monkton	....	....	....	....	....	....	....	....	....	50
,,	Camerton	....	....	32	16	2	40	....	3		
18	Cadbury and Miborne Post	....	....	....	....	90 to 100	....	240 to 250	90 to 150	420	
35	Cam Long Doron, Dursley	....	....	....	....	200	80	200	110 *		
19	Castle Carey (Ridge Barn Hill)	....	....	....	....	50	....	165	45 *		
,,	Chilcompton	138									
,,	Camerton Old Pit	174		48							
18	Chiselborough......................	....	....	....	....	160					
19	Clutton..............................	60 to 84									
,,	Chewton Mendip	200									

,,	Compton Dunston	....	609								
,,	Cranmore (East)	....	....	....	....	70 to 80					
,,	Cranmore (West	....	....	....	150 to 260	30					
35	Dodington and Tormarton	....	....	....	150 to 400	70 to 75	....	105 to 110	55 to 65	110 to 120	120
19	Dundry Hill	....	170	30		450		2	41 to 85		
,,	Dunkeston	63	228	198							
35	Easton Pit	57 to 72									
19	Farrington Gournay	20 to 33 *									
,,	Farmborough Pit	21 *	108	87							
35	Forester Hill	....	....	....	....	150	80	150	70		
19	Glastonbury Tor	400 *		40	300		14	190			
,,	Higher Littleton (Radford Pit)	6	27								
18	Ham Hill	....	....	....	....	170	....	165	65 *		
21	Ilminster	....	....	....	....	158					
19	Lansdown	....	....	40	225	125	....	35	100 to 130	120 to 135	35 to 120
,,	Lamgat Beacon	....	....	....	450	50	....	145	35 *	75	
,,	Mere (towards Vobster)	....	....	....	....	....	....	....	....	190	
18	Mosterton	....	....	....	....	280	....	180	40	300	
19	Mells New Pit	....	....	....	....	....	....	....	21		
,,	Nunney	....	....	....	....	....	....	....	80		
,,	Norton Hill Pit	19 to 54	118	40	8						
35	North Nibley	....	....	....	....	105					
,,	Patchway	....	....	32 *							
20	Pusiton	....	....	68 *							
35	Parkfield Pit	54									
19	Pastlebury Hill	....	....	....	....	....	....	....	60	190	
,,	Paulton	6	132 to 180	28	126						
,,	Priestbury	....	....	....	240						
35	Purton Passage	....	300 †								

		Dolomatic Conglomerata	Red Marl and Sandstone	Penarth Beds	Lower Lias	Middle Lias	Upper Lias	Midford Sands	Inferior Oolite	Fuller's Earth	Gr. Oolite
18	Queen Camel	....	150 *								
19	Queen Charlton and Burnet......	60 to 180		100							
”	Radstock	19	167		54–90		....	....	35		
”	Radstock (Upper Writhlington Pit)	4 *	102	21							
”	Radstock (Braysdown Pit)	6 to 20	159	187		....	....	....	36		
”	Stratton on the Fosse (Pitcot)...	32 to 96									
18	Sherbone	....	....	....	....	....	....	250	90 to 100		
19	Shepton Mallet	....	....	13							
”	Stantonbury............................	....	....	....	300	....	....	50			
”	Saltford	....	....	40	80						
”	Stowey Old Pit	6	51	30							
”	Stanton Drew	10	90	30 †							
”	Timsbury (Old Grove Pit)	11									
”	Tweston	150		60							
35	Uley Bury (Dursley)...............	....	....	....	....	180	90	200	100	110 to 150	
19	Widcomb Hill.........................										
35	Wotton Under Edge	....	....	....	....	198	10	139	80	128	
19	Whitchurch.................	....	....	24 *	....						

* 'Memoirs of the Geological Survey. Geology of East Somerset and the Bristol Coalfields.'
† 'Bath and West of England Agricultural Journal,' vol. xiv.

Marquis of Exeter, and a depth reached of 500 ft., but the Lias was not penetrated, the upper clay being above 140 ft. thick.

Water occurs on the same horizon, in the Uppingham *outlier*, issuing from a blue calcareous rock, forming the base of the Northampton sands, at Lyddington; springs also issue at Bisbrook.

The upper portion of the ironstones are much peroxidized, and readily pervious to water, and are called "kale" by the well-sinkers, the compact lower portion (carbonate of iron), is the water-bearing horizon, but the well-diggers consider it safer to penetrate it, and reach the Lias, "blue bind," to prevent failure during droughts.

Professor Judd states, the capacity for the absorption of rain, of the Northampton sands and over-lying oolite limestone, is "practically unlimited, for not only do many of the streams flowing over the boulder clay instantly disappear underground, by means of swallow holes, when they reach the junction of the clay and limestone or sand," but drains are carried into them, and artificial swallow-holes produced that never fail even in the heaviest rainfalls.

This water is given off in copious springs on the top of the lias, and though containing much temporary hardness, are never chalybeate.

The Northampton sands average twenty to thirty ft. in thickness, and seldom reach more than forty, the over-lying Lincolnshire oolite at Stamford is eighty ft., gradually thickening from thence northwards, and thinning out entirely southwards at Harrington and Maidwell, and eastwards, near Wansford tunnel.

C. E. De Rance. S. B. J. Skertchley.
Crooked drain near Norney, Ely:—

	Ft.	in.
Peat	11	0
Clay (fen)	3	0
Kimmeridge clay		
	14	0

Pit at the 70 milestone, between Littlepost and Ely:—

	Ft.	in.
Peat	1	6
Sandy loam	1	6
Kimmeridge clay	16	0
Stone floor (septarea)	1	3
	20	3

C. E. De Rance. Geological Survey.
Great Northern Railway boring, north side of River Cam, Chesterton:—

	Ft.	in.
Made ground	4	0
Black peat	2	0
Gravel	10	0
Kimmeridge clay	5	0
	21	0

Railway boring, Earith Wash:—

	Ft.	in.
Clay, yellow	2	6
Peat, black	3	6
Clay, yellow and mottled	4	0
Sand, gravel, and loam	5	0
Oxford clay	3	0
	18	0

S. B. J. Skertchley.
Near Gas Works, Whittlesey:—

	Ft.	in.
Gravel and sand	10	0
Oxford clay (seen)	5	0
	15	0

Downham Market, Bennet's brickyard:—

	Ft.	in.
Soil, sandy	2	0
Ferruginous sandy bed	0	10
Siliceous sand and fine gravel	1	8
Kimmeridge clay { dark blue clay	30	0
Kimmeridge clay { stone floor (septaria)	1	8
Dark blue clay	—	
	36	2

C. E. De Rance. Mr. C. B. Rose.
Lynn, Mr. T. Allen's well:—

	Ft.	in.
8 Vegetable soil	—	
7 Loam (silt)	7	0
6 Peat	2	6
5 Blue clay	8	0
4 Peat, with alder and hazel	3	0
3 Blue clay, with marine silt	30	0
2 Blue clay, with "chalk stones"	630	0
1 "Oxford clay," with septaria	—	

NOTE.—The greater part of 1 and 2 are probably Kimmeridge Clay, the upper part of 2 being referable to the Boulder Clay.

Stickney. Geological Survey:—

	Ft.	in.
Clayey silt	4	0
Peat, with trees	0	6
White silicious sand	2	0
Dark gravel, mixed with clay	6	0
Kimmeridge clay { Dark blue clay	32	0
Kimmeridge clay { Large septaria	2	0
Kimmeridge clay { Dark blue clay	—	
	46	6

Horbling Fen Farm:—

	Ft.	in.
Peaty soil	1	6
Clay, blue laminated (Oxford clay)	59	0
Rock bed, septaria course (do.)	1	3
	61	9

(Account of boring for water.)

BOSTON, Market Place :—
MS. in Geological Society's Library :—

	Ft.	in.
Light blue clay	36	0
Sand and gravel	1	6
Light blue clay	10	6
Rag stone, with salt springs	0	6
Dark blue clay	26	6
Light-coloured stone	0	6
Dark blue clay	38	6
Bright-coloured stone	0	8
Gravel, with salt springs	0	6
Dark clay	59	0
Chalkey clay, with pebbles and flints	0	6
Dark clay, with a bed of shells (? about 35 ft. down and about 6 ft. thick) } Dark clay	168	0
Chalky (? 6 in.) } Dark earth, with chalk and flints } Beds of do.	128	7
Rag stone	1	1
Dark silt, with chalk and gravel, no spring	—	
	472	4

SUTTON, Lincolnshire :—

	Feet
Clay	16
Moor or peat	4
Soft moor, with shells and silt	20
Marly clay	1
Chalky rock	2
Clay	93
Gravel and water (not bottomed)	—
	136

DONCASTER boring for water supply. Failed in obtaining water supply. Letter from W. Sheardown, 1867, to Mr. Hunt, Mining Record Office.

	Ft.	in.
Warp	4	0
Blue clay	14	0
Quicksand	2	0
Gravel	2	0
Red rock	90	0
Red clay	36	0
Limestone	0	4
Red clay	1	4
Limestone	0	8
Red clay	1	5
Limestone	0	1½
Red clay	0	6
Limestone	0	4½
Red shale	2	3
Limestone	0	1½
Shale limestone	6	0

	Ft.	in.
Blue Clay	0	3
Limestone	48	0
Blue clay	6	7
Red clay and sulphate of lime	42	0
Hexthorpe limestone	210	0
Blue shot	8	0
Firclay	18	0
Coal smut	18	0
Grit	0	9
Shaly clay	84	0
Grit	4	6
Shaly clay, and grit beds	244	6
	845	8½

Bore small and rods broke, and could not be raised.

Well section at Somerton at the west end of the town, about a quarter of a mile to the west of the brewery well. Communicated by Mr. F. H. Dickinson, F.G.S.

	Ft.	in.
Depth of well before beginning boring	62	0
Blue marl (soft)	0	7
White lias	2	8½
Blue marl (parting)	0	2½
White lias (very hard)	4	3
Greyish lias (soft with a black parting)	0	6
Blue marl	0	6
Bluish lias, hard; last 20 inches lies very hard	4	5
Greyish lias very hard	4	11
„ ditto „	2	9
„ ditto „	0	2
„ ditto „	2	1
Grit, sandy appearance	0	8
White lias (hard)	2	4
„ „	1	9
„ „	2	1
Greyish lias (soft)	2	10
White lias (very hard, mixed with alabaster)	3	4
Grey lias (tough)	2	0
Soft ditto	2	1½
Hard white ditto	1	1
Soft grey ditto	0	4½
Blue marl	3	2
Blackish ditto	0	9
Soft grey „	1	4
ditto „	0	9
Hard black stone	1	3½
Ditto	0	8½
Ditto	1	1
Ditto	1	9
Ditto	1	0
Ditto	1	6
Bluish lias	0	5
Light grey (hard)	2	6
	119	11

14 ft. or so below the river. [This seems to mean *bottom* of well.—W. W.]

FARRINGDON.—Eagle Brewery, ?1874. Sunk and communicated by Mr. W. B. Kinsey (with specimen of each bed).

Bore decreasing from 5½ to 3 in.

Water rose to within 13 ft. of the surface, but is reduced 25 ft. by pumping.

Supply, 12,700 gallons a day (of 11 hours).

Sand has blown up the pipe to 77 ft. from the surface.

		Feet.
[? Made ground]	Grit and stone	7½
	Dark grey sandy clay with bits of stone	4
[? Coral rag]	(1) Rock, loose for 1 foot, hard for 2 ft.	3
	(2) Oolitic rock	7½

(1) Water 54°. (2) Bottom of town wells.

			Feet.
[? Lower calcareous grit]		Grey clayey sand, firm	9½
		Grey sand, loose	9
		Grey clayey sand, firm	11
		Oolitic rock and clayey rock	2½
		Dark grey clay with a little sand	2
		Grey clayey sand, firm	8
		Rock (limestone)	6
	(3)	Light grey sharp sand	3
[? Oxford clay]		Grey sandy clay	13
		Grey sand with pyrites	5
	(4)	Grey sandy clay	4
		" " "	5
		" " "	13
			113

(3) Water 53°. (4) Water 52°.

BEDFORD.—Close to the River Ouse, about a mile N.W. of the town. Sunk by Mr. J. Lund, 1867; well 30 ft., bore 70 ft.

	Feet.
Soil	¾
Yellowish clay	8
Woody deposit	¼
Laminated limestone	8½
Laminated calcareous bed	¼
" rock	½
Close hard limestone	2½
Laminated calcareous matter	¼
Clay	9
Hard rock	4
Clay	65
Rock	1
	100

New Well, Spinning Close, Kettering Road, Northampton.

	Ft.	in.
Yellow clay and marl	4	0
Blue ditto and byne	147	0
Green rock with fossil shells	4	0
Binds with fossils	1	0
Green rock with shells	6	0
Rock binds	2	0
Hard green rock with fossils	7	6
Strong rock binds	2	6
Hard rock	3	6
Binds with fossils	8	0
Hard rock	2	6
Rock binds	3	6
Light coloured rock or 'Bastard Stone'	1	6
Strong binds with ironstone	20	0
Bottom of sinking 10 ft. diameter. Depth of sinking	213	0

SELECTED ANALYSIS MADE FOR THE RIVERS POLLUTION COMMISSION OF WATER DERIVED FROM THE OOLITIC ROCKS.

	Temperature Centigrade	Total Social Impurity	Organic Carbon	Organic Nitrogen	Ammonia	Nitrogen as Nitrates or Nitrite	Total Combined Nitrogen	Previous Sewage Contamination	Chlorine	Hardness: Temporary	Hardness: Permanent	Hardness: Total	Remarks
Spring Wate													
Bath, Hampton Down	8·1	22·40	·140	·007	0	·100	·107	680	1·30	15·1	3·5	18·6	Slightly turbid.
„ Egford Spring	10·0	30·76	·009	·004	0	·130	·134	980	1·46	21·8	5·4	27·2	Clear and palatable.
Yeovil (Somersetshire), water supply	8·5	24·76	·044	·077	·001	·300	·378	2690	1·65	14·8	6·1	20·9	Clear and palatable.
Nunney, near Frome, proposed for water supply	—	31·10	·011	·099	0	·255	·260	2230	1·26	19·1	6·0	25·1	Clear and palatable.
Chalford (Gloucestershire)	11·7	28·86	·083	·019	0	·285	·300	2530	·97	20·9	3·6	24·5	Clear and palatable.
Gloucester, source of Arle Brook	11·8	44·52	·040	·010	0	·026	·036	0	1·60	18·4	13·5	31·9	Clear and palatable.
Longford (Gloucestershire), source of Avon	10·3	25·56	·053	·007	0	·398	·405	3660	1·22	16·8	4·7	21·5	Clear and palatable.
Stroud (Gloucestershire), water supply from Gainer's Well	—	32 92	·014	·011	0	1·157	7·168	11,250	2·58	13·8	8·0	21·8	Clear and palatable.
Northampton, Garner's Spring	—	31·36	·009	·003	0	·790	·793	7580	1·76	17·4	5·9	23 3	Clear and palatable.
Warkton, near Kettering, (Northamptonshire), Cornwell's Spring	—	40·20	·071	·015	0	·682	·697	6500	1·95	24.3	6·3	30·6	Clear and palatable.
Thames Basin. Bourton-on-the-Water, Eyeford Spring	10·0	26·86	·028	·004	·001	·290	·295	2590	1·25	18·3	5·6	23·9	Clear and palatable.
Thames Basin. Cirencester, Cowley Springs	10·0	24·32	·027	·005	·001	·232	·238	2010	1·10	14·5	4·9	19·4	Clear and palatable.
Thames Basin. „ the Seven Springs	10·2	22·60	·012	·009	·001	·510	·520	4790	1·10	11·3	5·6	16·9	Clear and palatable.
Thames Basin. „ Syreford Spring	10·0	22·34	·029	·008	0	·222	·230	1900	1·20	13·8	5·1	18·9	Clear and palatable.
Thames Basin. Daventry, source of Cherwell	9·0	27·30	·023	·009		·434	·443	4020	1·70	16·7	5·7	22·4	Clear and palatable.
Thames Basin. Donnington Mill, a source of the Windrush	10·0	27·48	·039	·017	0	·347	·364	3150	1·40	17·3	6·6	23·9	Slightly turbid.
Thames Basin. Seizincote, Pope's Hole, source of Evenlode	9·9	25·82	·047	·0 10	·001	·690	·701	6590	2·20	12·0	7·1	19·1	Clear and palatable.

The Starveall, spring above coppice	9·5	28·76	·034	·012	0	·590	·602	5580	1·30	16·9	7·6	24·5	Clear and palatable.
Stow-on-the-Wold	9·9	24·44	·037	010	0	·753	·763	7210	1 40	14·3	6·3	20 6	
Taddington, a source of the Windrush	11·8	31·20	·047	·014	0	0	·011	0	1·10	25·7	4·3	30·0	Traces of iron.
Scarborough, Old Waterworks Supply, Cayton Bay	10·0	30·38	·030	·007	0	·074	·081	420	3·30	13·5	8·3	21·8	Clear and palatable.
Average	—	30·33	—	—	—	—	—	—	1·55	18·2	6·2	24·4	
Deep Well Water, Unpolluted.													
Stow-on-the-Wold (Gloucestershire) District Well, 120 ft. deep............	—	32·30	·028	·009	0	1·898	1·907	18,660	3·20	8·3	10·6	18 9	Clear and palatable.
Cirencester, Thames Head Well, 60 ft...	10·5	27·44	·037	·018	0	·316	·334	2840	1·35	18·0	5·0	23·0	
Northampton, Berrywood Estate Well...	—	26·60	·023	·005	·001	·374	·380	3430	1·80	11·4	5·6	20·0	Turbid, palatable.
Scarborough, Cayton new bore	12·0	41·90	·054	·011	0	·539	·550	5070	3·40	12·1	9·1	21·2	Clear and palatable.
" Grand Hotel bore, 214 ft...	12·2	39·78	·041	·008	·010	0	·009	590	3·70	16·1	3·6	19·7	
Average	—	33·60	—	—	—	—	—	—	2·69	13·8	6·8	20·6	
Shallow Well Waters.													
Bedford, Pillory pump.....................	—	140 74	·325	·88	0	2 497	2 585	24,650	15·29	29·1	25·4	54·5	
Brackley (Northamptonshire) Howard's.	—	84·88	·203	·085	0	4 432	4·517	44,000	7·90	10·8	33·5	44·3	
Warkton, Kettering Rectory	—	72·00	·266	·033	0	1·191	1·224	11,590	8 70	30·7	9·3	40 0	Clear and palatable.
Cirencester, Railway Station..............	—	59·20	·144	·019	0	·626	·645	5910	2·80	32·4	5·5	37·9	
Frome (Somersetshire), Blue House Stone	—	86·30	·367	·064	·025	2·525	2·610	25,140	6·67	29·4	20 9	50·3	
Faringdon (Berks), Hinton Manor	—	101·50	·201	·066	·001	3·510	3·577	34,790	11·05	42·6	24·5	67·1	
Thame, Town pump.....................	—	269·60	·759	·283	·006	12 220	12·508	121,930	44·50	23·0	55·9	78·9	Slightly turbid.
Witney (Oxfordshire)	—	145·00	·527	·250	·240	4·132	4·880	45,980	22·90	37·9	16·4	54·3	
Deep Well Waters, Polluted.													
Bourne (Lincolnshire), water supply ...	9·5	42·76	·217	·047	0	0	·047	0	2·10	23·4	11·8	35·2	
Witney, Clinch's Brewery, 65 ft. deep...	10·3	71·01	·142	·053	·001	·308	·362	2770	7·80	26·4	12 9	39·3	Clear and palatable.
Theescombe (Gloucestershire), 60 ft. deep	—	27·48	·106	·020	·002	·778	800	7480	2·50	12·6	8·6	21·2	

Boring $2\frac{3}{4}$ in. diameter.

	Ft	in.
Strong binds shale	18	0
Iron stone bind	0	6
Bind shale	0	6
Ironstone bind	0	6
Strong bind shale	32	0
Hard brown rock	1	0
Blue bind shale	29	0
Hard rock	1	6
Blue bind shale	5	6
Ironstone binds	0	5
Blue bind shale	20	7
Rock	2	6
Blue binds	18	0
Rock	1	0
Blue binds	21	0
Rock	2	6
Blue binds	3	0
	157	6

The Northampton Water-works Company.

From Mr. B. Latham's Paper, 'Trans. Soc. Eng.,' for 1864, pp. 244, 247. Shaft 120 ft., the rest bored.

Yield 518,000 gallons a day.

	Feet.
Made ground	3
Rubble stone	$13\frac{1}{2}$
Stone	6
Blue clunch	$135\frac{1}{4}$
Hard stone	$14\frac{1}{4}$
Clay stone	$18\frac{1}{2}$
Stone	$\frac{3}{4}$
Clay stone	$35\frac{1}{2}$
Stone	3
Clay stone	$23\frac{1}{4}$
	253

KETTERING Waterworks, 1872.—Nearly half a mile S.S.W. of Weekley Church. Communicated by Mr. T. Hennell, C.E.

Water level (at rest) in shaft No. 1. $9\frac{1}{2}$ ft. down; in shaft N. 2, 8 ft. down.

	Shaft No. 1 at Engine-House on slightly higher ground	Boring about $\frac{3}{4}$ of way to Shaft No. 2	Shaft No. 2, about 100 yards S E. of No. 1
Sand, to top of rock	$14\frac{1}{2}$	4	8
Shale [=soft rock]	$4\frac{1}{2}$	—	—
Rock	9	15	13
Tot. clay	28	19	21

No. 1 has three galleries, of a total length of 81 ft., and yields 120 gallons a minute.

No. 2, connected with No. 1 by a syphon, yields 360 gallons a minute.

These analyses show, in the words of the Commission, "that the oolitic rocks are not inferior to the New Red Sandstone, in the energy with which they oxidize and destroy the organic matter present in the waters percolating through them."

Though the waters so derived are generally hard, it is chiefly of a temporary character, capable of being softened by Clark's process, so as to average 6°·8 instead of 20°·6.

The oolites yield in springs and deep wells, water which is "bright, sparkling, and palatable," and "excellent for drinking and all domestic purposes, except washing," for which latter purpose, the addition of lime renders it fit.

It is noticeable that the temporary hardness of the deep well waters is higher than that of the spring water, where care has been taken.

Appendix—Form of Questions.

1.—*Position* of Well, or Wells with which you are acquainted.

2.—Approximate *height* of the same above the mean sea level.

3.—*Depth* from surface to bottom of shaft of well, with diameter. *Depth* from surface to bottom of bore-hole, with diameter.

4.—Height at which water stands *before* and *after* pumping. Number of hours elapsing before ordinary level is restored after pumping.

5.—*Quantity* capable of being pumped in gallons per day.

6.—Does the *water level* vary at different seasons of the year, and how? Has it diminished during the last 10 years?

7.—Is the ordinary *water level* ever affected by local rains, and if so, in how short a time? And how does it stand in regard to the level of the water in the neighbouring streams, or sea?

8.—*Analysis* of the water, if any? Does the water possess any marked *peculiarity*?

9.—Nature of the rock passed through, including cover of drift, with *thicknesses*.

10.—Does the cover of drift over the rock contain *surface springs*?

11.—If so, are they entirely kept *out* of the well?

12.—Are any large *faults* known to exist close to the well?

13.—Were any *salt springs* or brine wells passed through in making the well?

14.—Are there any *salt springs* in the neighbourhood?

15.—Have any wells or borings been discontinued in your neighbourhood, in consequence of the water being more or less *brackish*? If so, if possible, please give section in reply to query No. 9.

Report of the Committee, consisting of JAS. R. NAPIER, *F.R.S.*, Sir W. THOMSON, *F.R.S.*, W. FROUDE, *F.R.S.*, J. T. BOTTOMLEY, *and* OSBORNE REYNOLDS, *F.R.S. (Secretary), appointed to investigate the effect of Propellers on the Steering of Vessels.*

SINCE the Meeting of the British Association held in Plymouth last year, the Committee have had the satisfaction of receiving reports of the trials of various English and foreign steamers, made by the owners and officers of the steamers, without any further instigation from the Committee than that contained in their circulars. These reports all show that those by whom the trials were made have become convinced of the importance of

the facts which they have observed. And, indeed, the mere fact of the trials having been undertaken shows that the importance of the effect of the reversed screw on the steering while the ship is stopping herself is beginning to be recognised. This is further shown by the fact that one of the trials was undertaken at the instance of the Court of Mr. Stipendiary Yorke, in order to ascertain if the captain of the s.s. *Tabor* had been justified in starboarding his helm in order to bring his vessel round to starboard after his screw was reversed.

All these trials, without a single exception, confirm the results obtained in the previous trials made by the Committee. But this is not the most important purpose which this year's trials serve. For, as regards the general effect of the reversed screw on the action of the rudder, the trials already reported, particularly those of the *Hankow* (see last year's Report, p. 201), are conclusive, and leave nothing to be desired. But the previous trials were all made with fast vessels at their full draught, their screws being well covered, and the conditions of the weather being most favourable. The trials this year, on the other hand, appear, for the most part, to have been made with vessels in light trim; and in two instances the wind was blowing with considerable force. The result of these circumstances on the behaviour of the vessels is very decided, and coincides remarkably with the effects deduced by Professor Reynolds from his experiments on models (see Report 1875, i., p. 145), viz., that when the screw is not deeply immersed and froths the water, it exerts, when reversed, considerable influence to turn the vessel independently of the rudder; the vessel turning to starboard or port, according as the screw is right or left handed, which effect (and this seems to be the point most generally unknown) nearly disappears when the screw is so deeply immersed that it does not churn air with the water.

Neither the Admiralty, the Board of Trade, nor the Elder Brethren of Trinity House have taken any further notice of the results communicated to them by the Committee.

The Marine Board of South Shields has, however, taken considerable interest in the question, has invited captains to make trials, and Mr. J. Gillie, the Secretary, was present at the trial of the *Tabor* ordered by the Court, and reported the results to the Committee.

There have been numerous collisions during the year. In almost all cases the practice of reversing the screw has been adhered to. In many, if not in all instances where this has been done, the evidence goes to show that the vessel in which the screw was reversed did not turn in the direction in which those in charge of her were endeavouring to turn her. In two important cases this fact was fully apparent even to those in charge of the vessel. And in one instance the owners and captain of the vessel attributed the failure to steer to its true cause, namely, the reversal of the screw; although in both cases those immediately in charge of the vessels contended that the rudder was not handled according to their directions.

The first case was that of the *Menelaus* and the *Pilot* schooner on the Mersey. The *Menelaus* was in charge of a first-class pilot, and this steamer, in broad daylight, ran into and sank the *Pilot* schooner, which was dropping up the river with the tide. The pilot in charge contended that, owing to the wheel chains having got jammed, his orders were not attended to. The jamming of the chains was denied by the owners, and the fact that they subpœnaed the Secretary of the Committee

to give evidence at the trial may be taken to indicate the cause to which they attributed the collision. The case, however, was only in part heard, for after the evidence for the plaintiffs a compromise was effected, and the pilot withdrew all assertion that the wheel chains had been jammed, thus admitting that the failure to steer had been brought about by the reversal of the screw.

The other case is the well-known accident to the *Kurfurst*. In this it is admitted that the order was to starboard the helm and reverse the screw of the *Konig Wilhelm*, and this order was avowedly given with the view of bringing the vessel round to port. All the experiments of this Committee, however, go to prove that with a reversed screw and a starboard helm such a vessel as the *Konig Wilhelm* would have turned to starboard rather than port. This was what, according to all the evidence, did actually happen, and was the final cause of the catastrophe. But it appears that those in charge of the *Konig Wilhelm* arrived at the conclusion that the men at the wheel (and these would be many), although they all aver that they heard the order and obeyed it, in reality turned the wheel the wrong way. Considering, therefore, that it was not one man but a number of men at the wheel, and that the vessel behaved exactly as she would have behaved had the order been obeyed, as the men say it was, the conclusion of the Court seems to be most improbable, and, for the sake of future steering, most unfortunate.

The Committee are now of opinion that the work for which they were originally brought together has been fully accomplished. The importance of the effect of the reversed screw on the action of the rudder has been fully established, as well as the nature of its effect completely ascertained. Also for two years the Committee have urged the results of their work upon the attention of the Admiralty, and the various marine boards, and although they regret that as yet they have failed to obtain the general recognition of the facts brought to light which their vital importance demands, they consider that this will surely follow, and that as a Committee they can do no more than publish the reports of the trials, and the conclusions to which they have been led.

Full accounts of the experiments made previously to this year have been given in the two previous Reports, and those which the Committee have received this year are given at length at the end of this Report. The following is a summary of the conclusions which have been established; and it is interesting to notice that the conclusions drawn by Professor Reynolds from experiments on models have been fully confirmed by the experiments on full-sized ships:—

Summary of the Results of the Trials of the Effect of the Reversed Screw on the Steering during the time a vessel is stopping herself.

It appears both from the experiments made by the Committee, and from other evidence, that the distance required by a screw steamer to bring herself to rest from full speed by the reversal of her screw is independent, or nearly so, of the power of the engines, but depends on the size and build of the ship, and generally lies between four and six times the ship's length. It is to be borne in mind that it is to the behaviour of the ship during this interval that the following remarks apply.

The main point the Committee have had in view has been to ascertain how far the reversing of the screw in order to stop a ship did or did not

interfere with the action of the rudder during the interval of stopping; and it is as regards this point that the most important light has been thrown on the question of handling ships. It is found an invariable rule that, during the interval in which a ship is stopping herself by the reversal of her screw, the rudder produces none of its usual effect to turn the ship, but that, under these circumstances, the effect of the rudder, such as it is, is to turn the ship in the opposite direction from that in which she would turn if the screw were going ahead. The magnitude of this reverse effect of the rudder is always feeble, and is different for different ships, and even for the same ship under different conditions of loading.

It also appears from the trials that, owing to the feeble influence of the rudder over the ship during the interval in which she is stopping, she is then at the mercy of any other influences that may act upon her. Thus the wind, which always exerts an influence to turn the stem (or forward end) of the ship into the wind, but which influence is usually well under control of the rudder, may, when the screw is reversed, become paramount and cause the ship to turn in a direction the very opposite of that which is desired. Also the reversed screw will exercise an influence, which increases as the ship's way is diminished, to turn the ship to starboard or port according as it is right or left handed; this being particularly the case when the ships are in light draught.

These several influences—the reversed effect of the rudder, the effort of the wind, and the action of the screw—will determine the course the ship takes during the interval of stopping. They may balance, in which case the ship will go straight on, or any one of the three may predominate and so determine the course of the ship.

The utmost effect of these influences, when they all act in conjunction, as when the screw is right-handed, the helm starboarded, and the wind on the starboard side, is small as compared with the influence of the rudder as it acts when the ship is steaming ahead. In no instance has a ship tried by the Committee been able to turn with the screw reversed on a circle of less than double the radius of that on which she would turn when steaming ahead. So that, even if those in charge could govern the direction in which the ship will turn while stopping, she turns but slowly; whereas in point of fact those in charge have little or no control over this direction, and unless they are exceptionally well acquainted with the ship, they will be unable even to predict the direction.

It is easy to see, therefore, that if on approaching danger the screw be reversed, all idea of turning the ship out of the way of the danger must be abandoned. She may turn a little, and those in charge may know in which direction she will turn, or may even by using the rudder in an inverse manner be able to influence this direction, but the amount of turning must be small, and the direction very uncertain.

The question, therefore, as to the advisability of reversing the screw is simply a question as to whether the danger may be better avoided by stopping or by turning; a ship cannot do both with any certainty.

Which of these two courses it is better to follow, must depend on the particular circumstances of each particular case, but the following considerations would appear to show that when the helm is under sufficient command there can seldom be any doubt.

A screw steam-ship when at full speed requires five lengths, more or less, in which to stop herself; whereas by using her rudder and steaming on at full speed ahead, she should be able to turn herself through a quadrant,

without having advanced five lengths in her original direction. That is to say, a ship can turn a circle of not greater radius than four lengths more or less (see *Hankow*, *Valetta*, *Barge*) ; so that, even if running at full speed directly on to a straight coast, she should be able to save herself by steaming on ahead and using her rudder after she is too near to save herself by stopping; and any obliquity in the direction of approach, or any limit to the breadth of the object ahead, is all to the advantage of turning, but not at all so to stopping.

There is one consideration, however, with regard to the question of stopping or turning which must, according to the present custom, often have weight, although there can be but one opinion as to the viciousness of the custom. This consideration is the utter inability of the officers in charge to make any rapid use of the rudder so long as their engines are kept on ahead. It is no uncommon thing for the largest ships to be steered by as few as two men. And the mere fact of the wheel being so arranged that two men have command of the rudder, renders so many turns of the wheel necessary to bring the rudder over that, even where ready help is at hand, it takes a long time to turn the wheel round and round so as to put a large angle on the rudder.

The result is that it is often one or two minutes after the order is heard before there is any large angle on the rudder, and of course under these circumstances it is absurd to talk of making use of the turning qualities of a ship in case of emergency. The power available to turn the rudder should be proportional to the tonnage of the vessel, and there is no mechanical reason why the rudder of the largest vessel should not be brought hard over in less than fifteen seconds from the time the order is given. Had those in charge of steam-ships sufficient control over the rudder, it is probable that much less would be heard of the reversing of the engines in cases of imminent danger.

REPORTS OF THE TRIALS OF THIS YEAR.

s.s. NORTH-WESTERN, February 7, 1878.

Right-handed screw. Speed of ship 13 knots. Signalled to engine-room "Stop." "Full speed astern" 20 seconds after first order. Engines moving astern. Helm put hard a-starboard. Head commenced moving to starboard and went from N. 20 E. to N. 50 E. in 1½ minute. The vessel had by this time stopped going through the water. We then got up full speed ahead, stopped, put the helm hard a-port, and reversed full speed. The vessel had stopped going ahead in 1½ minute, and the head had gone to starboard from N. 30 E. to N. 50 E. At 2¼ minutes the head stopped going to starboard, and at 2½ minutes the ship's head was going to port. The vessel was going astern through the water before her head stopped going to starboard.

The draught of water was 9 feet 2 inches and 12 feet 10 inches. The centre of propeller is 7 feet 1 inches above bottom of keel, and the propeller is 13 feet in diameter, so that the top of the blade was 9 inches out of the water.

W. BOTTOMLEY, Jun.

Remarks by the Committee.

The screw of this vessel being right-handed, its tendency when reversed would be to bring the vessel's head to starboard, and, owing to

the screw being partially out of water, this tendency would be considerable. Accordingly we find that the direct effect of the screw prevailed over the influence of the rudder, and when the screw was reversed the vessel turned to starboard for all positions of the helm. The reversed effect of the rudder was, however, very apparent, for the vessel went to starboard while stopping much faster with the helm starboarded than with the helm ported.

The same phenomena exactly will be seen in the trials of the next four vessels.

Kongl. Gieenska Norsk General Consulatet i Stettin.

STETTIN, May 11, 1878.

SIR,—Being a subscriber to the 'Navy' I perused an article in No. 124, vol. v., of that journal (Oct. 7, 1876) regarding experiments on the turning of screw steamers.

The same inspired me with great interest in the matter it treats of, and caused me to instruct the captains of my three steamers, *Martha*, *Marietta*, *Susanne* (of which I subjoin the necessary particulars at foot), to make the experiments in question. This has been done, and the results obtained communicated to the Nautical Associations here and at other German ports. Being indebted to you, as the promoter of these experiments, for the idea, I consider it my duty to acquaint you with the results of the experiments made by my captains, and venture to enclose a translation of the report on same. I need not state that any comments you might favour me with, or a few lines stating whether the conclusions arrived at correspond to your own, would be most highly esteemed.

I am, Sir, your most obedient,

T. IVERS.

Professor Reynolds, Manchester.

On the Steering of Steamships with Right-handed Screws, when the vessel is going ahead, but her engines reversed.

The experiments made by Professor Reynolds, of Manchester, in reference to the correct steering of screw steamships, when going ahead with the propeller working astern, and the results of the trials made with the steamer *Melrose*, which have been published in the 'Glasgow News,' have induced us, the undersigned, to try the three chief manœuvres in question with the steamers which we command. We subjoin a statement of the results obtained, accompanied by sketch and explanation.

As screw steamers differ from each other in respect of model, construction, and size of propeller and helm, draught of water, &c., there is naturally a difference in the degree in which they deviate from a straight course when making these movements. We would, therefore, recommend every master to make experiments with his ship, with a view to ascertaining in what way the helm should be handled in all conceivable emergencies.

I. Ship going ahead, propeller working astern, rudder amidships.

Result. The stern turns to the right.

Explanation. The rotation of the screw to the left presses the stern to the left, and consequently the stem to the right; the helm, which is amid-

ships, is thus neutralised, and must be regarded merely as a prolongation of the ship.

II. Ship going ahead, the screw working backwards and the helm hard a-starboard.

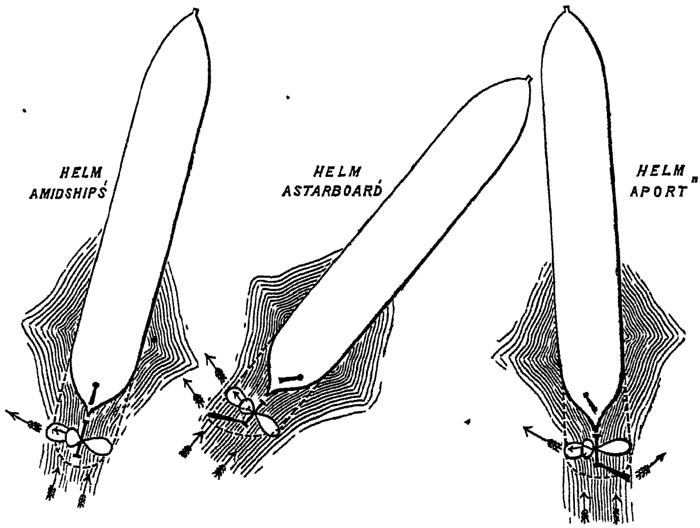
Result. The stern turns very decidedly to the right.

Explanation. The rotation of the screw to the left presses the stern to the left, and consequently the stem to the right; the starboarded helm is subjected to a pressure of water from behind, so that the after part of the ship is doubly impelled to the left, the fore part being also with correspondingly greater force pressed to the right.

III. The ship going ahead, propeller working astern, helm hard a-port.

Result. The stern inclines slightly to the left.

Explanation. The rotation of the screw to the left presses the after part of the ship to the left; on the other hand, the ported helm is under a



pressure of water from behind which impels the stern to the right. The operation of these two forces being of opposite nature, the vessel only deviates slightly from the straight course, and then mostly with the stern to the left.

But as soon as headway is lost the force of the screw asserts itself so much more that, in spite of the helm being ported, the stern turns to the left and the bow to the right; they turn in the same directions in a stronger degree when the helm is amidships, and strongest of all when the helm is starboarded. From the moment the ship begins to go astern the screw must be regarded as the fore end or bow of the ship. After the propeller, on the order "Full speed astern" being given, has made some few revolutions, there comes a short period during which the helm can be moved to either side with almost the same facility as when the vessel is lying stationary, after the expiration of which it almost immediately becomes necessary to use considerable force to work the helm. This is due to the circumstance that immediately after the screw has made the

first backward revolutions the pressure of water in front on the helm ceases, causing so-called deadwater at the helm; whereas an increasing pressure of water on the helm from behind results as soon as the backward revolutions of the screw begin to gain in rapidity. The pressure on the rudder from behind, in spite of the vessel's headway, is presumably to be attributed to the fact that the masses of water thrown forward by the screw must immediately be replaced, causing a correspondingly powerful suction, and consequently a current of water acting on the rudder. The conflict between the contending masses of water is clearly visible also on the surface on both sides of the ship (particularly on the right side).

We beg to hand these results of our observations to the Nautical Association of this town for distribution amongst other masters, and trust that they will likewise communicate the result of their experiments with their respective ships, in order that the data thus collected may be of service to the seafaring community.

(Signed) J. SCHÜTZ, Master of the s.s. *Susanne*.
„ F. WILKE, do. s.s. *Marietta*.
„ C. STREECK, do. s.s. *Martha*.

N.B.—The altered operation of the screw being in the main to be attributed to the fact that the backward revolutions transmute the pressure of water on the helm coming from in front to a pressure coming from behind, it is, when carrying out this manœuvre, of the greatest importance that the helm should first be turned after the screw has commenced to revolve backwards.

From the 'Shipping and Mercantile Gazette.'

In connexion with the Board of Trade inquiry recently held at South Shields, before Mr. Stipendiary Yorke, into the collision between the *Tabor* steamer, of Sunderland, and the brig *William and Ann*, of Seaham, which happened in the River Thames, on January 25 last, some experiments have been made on board the *Tabor*, at the mouth of the Tyne, on the peculiar effects of the rudder and screw when reversed while the ship has headway, to turn the ship's head to starboard of her course. As far as I am aware, the first public intimation of any similar trials having been made appeared in the Report of the British Association for the year 1876. The Report gives an account of certain experiments made on the Clyde by Professor Osborne Reynolds, Sir William Thomson, Mr. James R. Napier, and others. These experiments were undertaken to verify certain trials made upon models by Professor Reynolds, which he had brought under the notice of the Association the previous year at Bristol. An able article on the subject, from the pen of Sir Travers Twiss, appeared in the 'Nautical Magazine,' last year; so that nautical men should now be aware that they cannot always depend upon the action of the rudder and screw when reversed while the ship has headway.

Almost all experienced officers of the navy and merchant service are doubtless well acquainted with the manœuvring of screw vessels under steam, but it is thought that junior officers and others might not have had opportunities of acquiring information of this kind. There is a marked difference in the results observed on the Clyde and those noticed at the mouth of the Tyne, inasmuch as in none of the trials detailed below

did the ship's head swing to port of her course, but invariably to starboard. I would have preferred to wait until these differences had been either accounted for or explained by further experiments before placing the facts before your readers; but an imperfect account of the trials having appeared in the local newspapers, it was thought desirable to publish the facts just as they were obtained, and to reserve for a future letter further remarks, and a description of a series of similar experiments made by direction of the Local Marine Board on board the *Cervin* steamer, off the Tyne in August last year.

While the inquiry in reference to the *Tabor* collision was pending, Captain Henderson, the Secretary to the British Shipmasters' and Officers' Protection Society, suggested to the owner of that ship the importance of trying some experiments on the effect of the rudder and screw when reversed. Mr. Westall, the owner, immediately gave instructions to his manager to place the ship, which was then in the Tyne, at the disposal of of Mr. Yorke. That gentleman, thinking that it was a point of some interest to mercantile and nautical men to have the matter settled by actual trial, requested Messrs. Gillie and Tate, the Examiners to the Tyne and Wear Local Marine Boards, to accompany the ship to sea, and have the experiments carried out under their inspection.

On the 19th inst. the *Tabor* was unmoored from Shields Harbour, and at 2 P.M. proceeded to sea in charge of a pilot and Captain Mankin. There were also on board Rear-Admiral Powell and Captain Nicholas, the Nautical Assessors; Mr. L. V. Hamel, Solicitor to the Board of Trade; Captain Henderson, Secretary to the British Shipmasters' and Officers' Protection Society, and Mr. Roche, their solicitor; Alderman Peckett, of Sunderland; Captain Mail, manager for Mr. Westall, the owner, and others.

The ship was run out to sea three or four miles so as to be out of the way of passing vessels. The *Tabor* is a screw steamer of 520 tons register. Her length between perpendiculars is 208 feet; breadth, 27·8 feet; depth, 14·8 feet. She is propelled by two engines of 90-horse power combined, and at the time of the trial had in about 200 tons of water ballast. Her draught of water forward was 6 feet 6 inches, and aft 10 feet 4 inches, she being nearly in the same trim as she was at the time the collision happened. Her screw is right-handed, and four blades; diameter, 12 feet; pitch, 17 feet. The top of the blade was about 2 feet out of the water when the blade was parallel with the sternpost. The direction of the wind was S. by W. $\frac{1}{2}$ W.; force 4 to 5. The sea was perfectly smooth. The weather being a little hazy, and the marks upon the land indistinct, a dumb card could not be used to measure the angles made by the ship's head, but the bridge compass, being in excellent condition and not sluggish, was used for this purpose. Mr. Tate and Mr. Hamel noted the time, the change in the ship's head was observed by Mr. Gillie, who also took down the notes, and Mr. Roche noted the time it took to stop and reverse the engines. The ship's head previous to commencing the whole of the trials was steadied at W.S.W., and the engines were kept going full speed ahead, the ship making 8 knots an hour as shown by the patent log. The fore and main trysails were set during trials 1 and 2; there was no canvas set during trials 3, 4, and 5.

Trial No. 1 (helm hard a-starboard).—At 3.43 P.M., while the ship was going full speed ahead, the order was given to stop and reverse the engines to full speed astern, at the same time the helm was put hard to

starboard, both operations being done simultaneously, and completed in 12 seconds from the time of the order being given. In 40 seconds ship's head fell off to starboard of W.S.W. 10 degrees; in 1 minute 30 seconds ship's head fell off to starboard of W.S.W. 34 degrees; in 2 minutes 45 seconds ship's head fell off to starboard of W.S.W. 67 degrees, and the ship's way through the water ahead was completely stopped.

Trial No. 2 (with helm hard a-port), the ship's head being brought to W.S.W., going full speed, all other conditions as in trial 1.—In 40 seconds ship's head fell off to starboard of W.S.W. 12 degrees; in 1 minute 30 seconds ship's head fell off to starboard of W.S.W. 23 degrees; in 2 minutes 45 seconds ship's head fell off to starboard of W.S.W. 42 degrees, and the ship's way through the water ahead completely stopped.

Trial No. 3 (with helm amidships), fore and main trysails taken in, all other conditions as before.—In 40 seconds ship's head fell off to starboard of W.S.W. 15 degrees; in 1 minute 30 seconds ship's head fell off to starboard of W.S.W. 50 degrees; in 2 minutes 45 seconds ship's head fell off to starboard of W.S.W. 79 degrees, and way stopped.

Trial No. 4 (with helm hard a-starboard), being trial No. 1 repeated with no canvas set, all other conditions as before.—In 40 seconds ship's head fell off to starboard of W.S W. 7 degrees; in 1 minute 30 seconds ship's head fell off to starboard of W.S.W. 45 degrees; in 2 minutes 45 seconds ship's head fell off to starboard of W.S.W. 78 degrees, and way stopped.

Trial No. 5 (with helm hard a-port), being trial No. 2 repeated with no canvas set.—In 40 seconds ship's head fell off to starboard of W.S.W. 16 degrees; in 1 minute 30 seconds ship's head fell off to starboard of W.S.W. 34 degrees; in 2 minutes 25 seconds ship's head fell off to starboard of W.S.W. 45 degrees. At this point the engines were stopped by mistake, but the ship's head appeared to be fixed at W.N.W., and she had very little, if any, way through the water ahead.

The practical result of these trials, as far as the *Tabor* is concerned, is to show that when she is going full speed ahead in ballast trim, if her engines are stopped and reversed, her head will go to starboard of the course she is steering. The helm seems to have very little effect, the results obtained with the helm hard a-starboard and when it was amidships being very much alike. With the helm hard a-port the ship's head still went to starboard, but the angle described was much smaller than that made when the helm was amidships or a-starboard. I will not at present trespass any further on your space, but perhaps you will allow me to add that the experiments made with the *Cervin* steamer, with a draught of 22 feet, go a long way to show that, in ships of her class, similar results to those detailed above will follow under similar circumstances.

John Gillie.

Local Marine Board, South Shields, February 22, 1878.

Remarks by the Committee.

It will be seen that the results in this case are very similar to those obtained in the case of the *North-Western*. The right-handed screw only partially immersed gave the vessel a strong bias to starboard. But in this case, in addition to the direct effect of the screw, the effect of the wind, which was of force 4 or 5, was to bring the vessel round to windward, which happened in all cases to be to starboard

In the next vessel reported, the *Cervin*, it will be seen that the screw was well immersed, and hence would probably exert no great influence when reversed to turn the vessel to starboard. At the commencement of all the trials, however, the wind was blowing with force 5 on the starboard side of the vessel, and the effect of this would be to cause the vessel, as long as she had way on, to turn to windward, and this, it will be seen, is what happened; in every case the vessel's head turned to windward. Here also the reverse influence of the rudder was apparent, for the vessel turned faster to starboard with the helm starboarded than with it ported.

August 25, 1877.

S.s. *Cervin*, of South Shields, length, 287 feet; breadth, 34 feet; depth, 24 feet; tonnage, 1913. Propelled by two engines of 180 h p, combined; screw right-handed, 4 blades; diameter, 14 feet 9 inches; pitch, 17 feet; draught of water, forward 21 feet 4 inches, aft 21 feet 9 inches; top of blade of screw immersed in water, about 5 feet; wind, E.N.E.; force, 5; sea smooth.

Trial No. 1 (helm hard a-port).—Ship's head N. by W., going full speed ahead, 9½ knots, the engines were stopped and reversed, and helm put hard to port; ship's head came up to N. by E. in 2 minutes, and remained steady on that point; way through the water ahead stopped in 3 minutes 40 seconds.

Trial No. 2 (helm hard a-starboard).—Ship's head N. by E., it came up to N.E. by E., or 45 degrees, in 4 minutes, and way stopped.

Trial No. 3 (going fast astern, screw started to drive her ahead, helm a-port).—Head N. by W., fell off to N.N.W. in 1 minute 30 seconds.

Trial No. 4 (with helm a-starboard).—Head at N.E., fell off to N.N.E. in 2 minutes.

Trial No. 5 (full speed ahead, helm amidships)—Head N. by W., went slightly towards west, then back to north, in 3 minutes.

J. Gillie.

TRANSACTIONS OF THE SECTIONS

TRANSACTIONS OF THE SECTIONS.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

PRESIDENT OF THE SECTION—The Rev. Professor Salmon, D.D., D.C.L., LL.D., F.R.S., M.R.I.A.

THURSDAY, AUGUST 15, 1878.

The following Papers were read:—

1. *Report of the Committee on Underground Temperature.*

See Reports, p. 178.

2. *Report of the Committee on the Mechanical Equivalent of Heat.*

See Reports, p. 102.

3. *An Account of some Experiments on Specific Inductive Capacity.* By* J. E. H. GORDON, *Assistant Secretary of the British Association.*

4. *On the Effect of Variation of Pressure on the Length of Disruptive Discharge in Air. By* J. E. H. GORDON, *Assistant Secretary of the British Association.*†

The author has worked with a 17-inch induction coil, and with sparks varying from 6 to 10 inches at atmospheric pressure, and up to over 36 inches at low pressure.

Two "aurora tubes" were used, and the method of working was to allow the discharge to take its choice of two paths, one short at high pressure, and the other longer at lower pressure, and thus to compare the resistance to discharge at the different pressures. In the tables which accompany the paper, experiments at 55 different pressures, ranging from 2·42 inches to 29·7 inches, are given.

The general results deduced are—

(1) From a pressure of about 11 inches to that of the atmosphere, Harris's‡ law—namely, that the spark length varies inversely as the pressure—is approximately true.

(2) No law can be said to be more than approximately true, as when the electric density has almost reached the discharging limit, any slight accidental circumstance will cause the discharge to take place.

(3) Below about 11 inches a much greater electromotive force per unit length

* See 'Proc. Roy. Soc. 1878–79.' The experiments described in this paper were shown at the Royal Dublin Society's Soirée the same evening.

† 'Phil. Mag.' Sept. 1878. ‡ 'Phil. Trans.' 1834.

of air is required to produce a spark than at higher pressure. This is not inconsistent with Sir William Thomson's result, namely, that a greater electromotive force per unit length of air is required to produce a spark at short distances than at long.*

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5. *On the Absorption Spectrum of Chlorochromic Anhydride. By* G. JOHNSTONE STONEY, *M.A., F.R.S., Secretary to the Queen's University in Ireland, and* J. EMERSON REYNOLDS, *M.D., F.C.S., Professor of Chemistry in the University of Dublin.*

The authors described and exhibited the absorption spectrum produced by the vapour of chlorochromic anhydride ($C_2O_2Cl_2$). This spectrum is of peculiar interest from its having supplied information as to the duration and character of a motion within the molecules of the vapour (see 'Philosophical Magazine' for July, 1871). The spectrum consists of lines very regularly distributed over the orange yellow and green, bordering a more refrangible region of complete absorption. The lines are found to be equally spaced when plotted down on a map of oscillation-frequencies, and the intensities of the successive lines are such as to form definite patterns. From the *positions* of the lines, of which 105 had been examined, it has been ascertained that they are to be referred to one motion in the molecules of the gas, since they are all either its harmonics or such quasi-harmonics as, for example, occur when an elastic rod is made to vibrate transversely, most of which cannot be distinguished by observation from true harmonics. We further learn from the positions of the lines that this motion, on the more probable supposition that the lines are its true harmonics, is repeated 810,000,000,000 times every second in each molecule. And from the *succession of intensities* we learn that this molecular motion is in some way related to that of a particular point on a violin-string when vibrating under the influence of the bow, viz., a point nearly but not quite two-fifths of the length of the string from one end (see 'Philosophical Magazine,' loc. cit., p. 47).

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6. *On the Flow of Water in uniform régime in Rivers and in Open Channels generally. By* Professor JAMES THOMSON, *LL.D., D.Sc., F.R.S.*

The communication of which the following is an abstract was made to the Mathematical and Physical Section, in order to offer for consideration there a new theory of some of the phenomena of the flow of water in rivers and in open channels generally, which formed the subject of a paper just before sent to the Royal Society. The author stated that during a great part of the present century experimental investigations had been accumulating, made on some of the largest rivers in the world, and on aqueducts and on small artificial channels, which tended strongly to show that usually the velocity of flow at and near the surface of a river is less than the velocity at some depth between the surface and the bottom. They seem to show that for descent from the surface towards the bottom the velocity first increases till a maximum is attained, and farther down goes on diminishing for approach towards the resisting bottom. Now this has appeared very generally, even to the investigators themselves who have carried out the experiments, to be a very perplexing result, because it has seemed, through various modes of consideration, that the surface and upper portions of the current, being farther distant from the resisting bed, should be expected to be less influenced by its resistance, and should, therefore, flow faster than the parts intervening between them and the bottom. The principal object of the paper was to offer a new theoretical view explaining and accounting for the observed phenomenon which now appears to be highly probable, if not absolutely ascertained through experiments, and which these theoretical considerations of the author go to confirm. He says that

* Papers on Electrostatics and Magnetism, § 323, p. 248.

if we watch the surfaces of flowing rivers, or of tidal currents flowing in narrows or kyles, we may often have opportunity to observe very prevalent indications of rushes of water coming up to the surface and spreading out there. He considers that these proceed from the bottom, being driven upwards in consequence of impulses arising through the scouring action of the current along the bed. Thus the water so arriving to the surface and spreading out there is composed largely of the deadened water from the bottom—deadened as to forward motion by the intense fluid friction at the bottom. The superficial layer, thus always fresh from the bottom, becomes in its turn overflowed by new supplies from the bottom, and so it gradually descends to enter into the middle body of the stream. At the same time it is perpetually under the accelerating influence of the earth's attraction, in virtue of its downhill flow, and so it attains increase of velocity beyond that which it had at the surface.

7. *Note on the Pedetic Action of Soap.** *By* Professor W. Stanley Jevons, *F.R.S.*

Since the publication, in the 'Quarterly Journal of Science,' for April 1878, of the author's paper on the so-called Brownian movement of microscopic particles, which he proposes to term *Pedesis*, it has been suggested that soap would form a good critical substance for experiment in relation to this phenomenon. Soap considerably reduces the surface-tension of water, in which it is dissolved without much affecting, as is said, its electric conductibility. If, then, pedesis be due to surface-tension, as some physicists assert, the motion would be killed, or much lessened, when soap is dissolved in the water. The experiment having been tried with china-clay, red oxide of iron, chalk, barium carbonate, &c., gave the opposite result; the pedetic motion appeared to be increased and facilitated. A similar result was obtained by experiments upon the suspension of china-clay in dilute solutions of soap; it was found that soap distinctly prevented the precipitation of the suspended powder, and this result was obtained even in the presence of 1 per cent. of sodium carbonate.

The author believes that these results are in favour of his own opinion that pedesis is a phenomenon of electric origin, and can only go on in liquids of high electric resistance. He also points out that the detergent action of soap is probably due to the increase of pedetic action, which causes particles to become detached and suspended in the soapy liquid. Only in this way can we understand the utility of combining an alkaline salt with stearic or other fatty acid. So far as the action of soap depends on the alkali, it would be more active in the absence of the other constituent, which he therefore infers is only needed to maintain the pedetic and suspensive power of the water. The author believes that this is only one of many phenomena which may be explained by the study of pedesis; and he proposes to follow up the inquiry with regard to several substances tending to increase the motion.

8. *Motions produced by Dilute Acids on some Amalgam Surfaces.* *By* Robert Sabine.

The author finds, when a drop of very dilute acid is placed upon the clean and newly-filtered surface of a rather rich amalgam of some metal which is positive to mercury, that the drop does not lie still as it would do upon pure mercury, but sets itself into an irregular jerky motion. This is the case with copper, zinc, antimony, tin, and lead amalgams. But if instead of these amalgams, those of platinum, gold, and silver are used—these latter metals being negative to mercury—the drop of acid water lies quite still. The acids tried were: sulphuric, hydrochloric, oxalic, and acetic, which behaved similarly, but in different degrees.

When the experiment is made in an atmosphere of oxygen, the movements

* Printed in the 'Quarterly Journal of Science' for October 1878, vol. viii. N.S. p. 514; and in 'Nature,' August 22, 1878, vol. xviii. p. 440.

upon the amalgams of the positive metals are increased; but in hydrogen, carbonic acid, nitrogen, and coal-gas, the motions are instantly arrested.

The author concludes that the motions result from an alternate play of deoxidation of the mercury underneath the acid by electrolysis, due to the currents of small floating particles of the positive metal, causing the drop to contract, and of oxidation of the surface outside the acid-drop, causing it to re-expand.

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9. *Note on Surface Tension.* *By* GEORGE FRANCIS FITZGERALD.

Assuming that the contact difference of electric potential at the junction of two dissimilar fluids is due to a tendency towards some chemical combination of the two, it is easy to see that if χ be the electrical charge corresponding to each electro-chemical equivalent, which is the same for all bodies, and if n be the number of such equivalents in presence of one another per unit of surface, and if ϵ be the difference of potential of contact, then there is a potential energy per unit of surface $= n\chi\epsilon$ and this must be the superficial tension if it be all due to this cause, as M. Lippman's recent experiments seem to show. Hence

$$T = n\chi\epsilon.$$

If ϵ be assumed about ·1 of a volt, and $T = {\cdot}08$ grammes per centimeter, as it is in the case of water, it is possible to calculate the thickness of the superficial layer which contains molecules which act upon one another, and the result is

$$\theta = 7{\cdot}8 \times 10^{-8} \text{ of a centimeter,}$$

which approximates towards the quantities obtained by other methods.

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10. *New Application of Gas for Lighthouses, illustrated by Models, full-sized Apparatus, &c.** *By* J. R. WIGHAM, *M.R.I.A.*

I. The Quadriform Group Flashing Light at Galley Head Lighthouse.

The following are the chief points insisted on by the author:—

Importance of the position of Galley Head. Desire of the Commissioners of Irish Lights to obtain the best light there. Principle of Wigham's patent gas-burner explained. Result, the greatest possible intensity of light, combined with large volume. Method of increasing the power of burner by 5 steps, according to the state of the weather. Effect of lenticular apparatus upon such flames. Effect upon fogs of such flames. Method of still further increasing their power by doubling, trebling, and quadrupling the number of burners and lenses in each lighthouse. Method of arrangement so as to admit of one light being over another, not only without injury to the upper lights, but so as to give each of them increased illuminating power. Burners, lighthouse lens, and model of Galley Head Lighthouse to illustrate the above. A first-order quadriform light, by permission of the Commissioners of Irish Lights, exhibited at Howth Bailey Lighthouse, entrance to Dublin Bay, during the meeting of the British Association. Place of observation—Salt-hill, Kingstown. Importance of flashing great lights in suddenly illuminating fog, so as to arrest the eye of the mariner when the light itself is invisible.

II. The Combined Gas and Electric Light for Lighthouses.

In this paper the author discussed:—

Limit as to size of lighthouse lights attained by the quadriform light referred to above in Part I. Further intensity desirable. Core light introduced into focus of lenticular apparatus. Various kinds of cores—magnesium, lime light, &c. Improvement in the Gramme machine rendered electric light suitable as a core. Jablachkoff candle available. Effect of the electric core. Cost of same. Power of sudden flashes of electric light upon fog in arresting the attention of the mariner. There was an exhibition of this core light at Howth Bailey, by permission of the

* These papers were published in *extenso* in 'Engineering,' August 23, 1878.

Commissioners of Irish Lights. The light was so powerful as to enable the British Association programme to be read at a distance of about six miles.

III. A Mode of Lighting Sea Beacons from a Position on Shore.

The author pointed out the convenience of using gas for this purpose, and noted the arrangement by which this is done. Difficulty of maintaining small lights at low pressure. A series of beacon or harbour lights may be maintained by this plan, the initial pressure on shore being about six inches. Thus the lights would be raised by turning off the gas, and lowered by turning it on. To illustrate this, lights in various parts of the lecture room controlled in this way from the lecture table.

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11. *A Short Description of two kinds of Fog Signals.** *By* J. R. Wigham, *M.R.I.A.*

I. Gas Guns as Fog Signals.

The author mentions the importance to navigation of audible fog signals, and origin of gas guns. The important peculiarity of this mode of fog signalling, is that the gun may be placed on an isolated rock at sea, probably inaccessible in most weathers, and perhaps almost too small to hold an ordinary gun, and charged and loaded from a position on shore. The gas gun is unaffected by the action of water. As a practical illustration a small gun was fixed in the College Park, and charged and fired from the lecture room. The sound of the gas gun was equal to that of an 18 pounder. The flash of the gas gun is very useful as a fog signal, being more vivid than that of gunpowder.

II. The Irish Siren Fog Signal.

The United States Lighthouse Board was the first to introduce the Siren as a fog signal. The author alluded to the action of Dr. Tyndall and the Trinity House, Sir William Thomson and Sir Richard Collinson. The Irish Siren is less complicated and less cumbrous than those heretofore used. An Irish Siren was exhibited on the lecture table, and sounded at the conversazione of the Royal Dublin Society on Thursday, the 15th inst.

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12. *A New Atmospheric Gas Machine.* *By* J. R. Wigham, *M.R.I.A.*

The author exhibited one of these machines, and explained his invention.

* Published *in extenso* in 'Engineering' of August 23, 1878.

FRIDAY, AUGUST 16, 1878.

The following Papers were read:—

1. *Report of Committee on the Oscillation-Frequencies of the Rays of the Solar Spectrum. By* G. JOHNSTONE STONEY.—See Reports, p. 37.

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2. *General Results of some Recent Experiments upon the Co-efficient of Friction between Surfaces Moving at High Velocities. By* DOUGLAS GALTON, *C.B., D.C.L., F.R.S., &c.*

The author of this paper has been recently engaged in making some experiments upon the co-efficient of friction when the surfaces in contact move at high velocities, in connection with the action of brakes in use on railways; and the results which have been arrived at appear to present some interesting features in respect of the laws which govern the co-efficient of friction.

The experiments were made to ascertain the friction between the brake blocks and the wheels of a railway carriage.

The levers which move the brake blocks were fitted with dynamometers to show first, the pressure which was applied to force the blocks against the wheel; and secondly, the force or tangential strain exerted between the wheel and the block when the latter is pressed against the wheel.

The dynamometers used were adaptations of Richards' indicators, which act by water pressure, which transfers the pressure to cylinders fitted with pistons to which a pencil is attached, so as to register the pressure over a travelling sheet of paper, as is used with steam indicator diagrams. A dynamometer on a similar principle was attached to the draw bar so as to register the force exerted during the experiment in drawing the carriage.

The speed was also recorded on the diagram by means of the Westinghouse speed indicator, which also acts by water pressure, and depends for its action on the speed of revolution of the axles.

The carriage or van fitted with the apparatus had two pairs of wheels—one pair of wheels was fitted with brakes, whilst the other pair was free. A speed indicator was attached to each pair of wheels, so that the speed of the carriage could be ascertained at any time, independently of the speed of the braked wheels.

To check the Westinghouse speed indicator, two of Stroudley's speed indicators were also attached to the van; but these do not register automatically.

The distribution of the weight of the van between the two pairs of wheels was obtained, as well as the weight of the wheels and axles themselves.

In order to ascertain the weight thrown on the braked wheels during the progress of the experiment, a dynamometer fitted to the springs of the van showed the weight at every moment carried on the unbraked wheels, from which information it was easy to deduce the weight on the braked wheels.

The apparatus was designed by Mr. Westinghouse, and constructed under his supervision by the Brighton Railway Company, through whose assistance these experiments were carried into effect.

The effect of applying the brake to the wheels is twofold. So long as the

wheels to which brakes are applied continue to revolve at the rate of rotation due to the forward movement of the train, the effect of the brake is to create retardation by the friction between the block and the wheel; but when the pressure applied to the blocks causes the friction to exceed the adhesion between the wheels and rail, the rotation of the wheels is arrested, and the wheel becomes fixed and slides on the rail, being held in its fixed position by the brake blocks.

Therefore the experiments give the co-efficient of friction—1st, between the brake blocks and the wheel, which is equal to

$$\frac{\text{the tangential force}}{\text{the pressure applied}};$$

2nd, between the wheel and the rail, which is the

$$\frac{\text{friction of the brake blocks}}{\text{weight upon the wheels}}.$$

It has been generally stated that there is no difference in the co-efficient of friction observed in the case of bodies at rest, *i.e.*, in a condition of static friction, and the co-efficient of friction in the case of moving bodies, *i.e.*, in a condition of kinetic friction; but Mr. Fleeming Jenkin, in his paper read before the Royal Society in April, 1877, upon the friction between surfaces moving at very low speeds, alludes to the fact that in all cases where a difference in the co-efficient of friction is observed between static and kinetic friction, the static friction exceeds the kinetic.

Coulomb also points out in his experiments that in the case of static friction the co-efficient of friction increased with the time during which the bodies had been at rest.

The experiments of Coulomb, Rennie, Morin, and Jenkin were made with bodies moving at comparatively low velocities.

The following table shows the mean results obtained from a large number of the experiments made with the apparatus above described, upon the action between the cast-iron brake blocks and the wheels fitted with steel tyres:—

Average		Co-efficient of friction between cast-iron brake blocks and steel tyres of wheels			
Miles per hour	Feet per second	At commencement of Experiment, *e.g.* to 3 seconds	At from 5 to 7 seconds	At 12 to 16 seconds	At 24 to 25 seconds
60	88	·062	·054	·048	·043
55					
50	73	·100	·070	·056	
45	65	·125			
40	58	·134	·100	·080	
30	43	·184	·111	·098	
20	29	·205	·175	·128	·070
10	14	·320	·209		
under 5	7	·360			
Fleeming Jenkin—Steel on Steel Dry	·0002 to ·0086	·351 mean ·365 maximum			
Morin—Iron on Iron . . .		·44			
Rennie—At pressure of 1·6 cwt. per sq. inch					
Wrought iron on cast iron.		·275			
Steel on cast iron . .		·300			

A limited number of experiments were made with wrought-iron blocks upon steel tyres, a mean of which gave the following result:—

Average		Co-efficient of friction between wrought-iron blocks & steel tyre			
Miles per hour	Feet per second	At commencement of Experiment to 3 seconds	At from 5 to 7 seconds	At 12 to 16 seconds	At 24 to 25 seconds
48	—	·110			
31	—	·129	·11	·099	
18	—	·170			

The following table shows the result obtained by the sliding of the wheel on the rail—that is, a steel tyre on a steel rail:—

Average		Co-efficient of friction between wheel on rail—steel on steel			
Miles per hour	Feet per second	At commencement of Experiment to 3 seconds	At from 5 to 7 seconds	At 12 to 16 seconds	At 24 to 25 seconds
50		·04			
45		·051			
38		·057	·044	·044	
25		·080	·074		
15		·087			
10		·110			

The general results of these tables show that the co-efficient of friction between moving surfaces varies inversely in a ratio dependent upon the velocity at which the surfaces are moving past each other; probably the equation would be of the form of $\frac{a}{b+v}$.

The co-efficient of friction, moreover, at these velocities becomes smaller also after the bodies have been in contact for a short time. That is to say, the longer the time the surfaces are in contact, the smaller, apparently, does the co-efficient of friction become. This result appears more marked in the case of cast-iron blocks, than of the wheel sliding on the rail. This effect, however, does not appear to be unnatural; as the friction develops heat, and the consequent expansion tends to close up the pores, and to make the heated surface a more united surface than the colder surface. Besides which, it is probable that in the act of rubbing, small particles may be detached which may act as rollers between the surfaces.

It will also be observed that the co-efficient of friction between the cast-iron block and the steel tyre is much larger than that between the steel tyre of the wheel and the rails, which were also generally of steel.

As has been above mentioned, the sliding of the wheel on the rail takes place when the friction of the brake blocks is greater than the adhesion between the wheel and the rail, which is due to the weight upon the wheel. This was found to amount generally to about 24 to 28 per cent. of the weight.

The influence which these results have upon brakes for railway trains may be briefly summed up as follows.

In order to produce a given result at different velocities, the pressure applied to the brake blocks must increase in the proportion shown by the co-efficient of friction.

Thus at 50 miles an hour, the pressure required to make one pair of wheels

slide on the rail was nearly 27,000 lbs.; whilst at 20 miles an hour, a pressure of about 10,300 lbs. was found sufficient to obtain the same result.

The strain on the drawbar showed that the retarding force or the tangential strain between the brake-blocks and the wheels followed very nearly the same law of variation. That is to say, in order to produce a degree of friction on the wheel at 50 miles an hour, which shall exert a retarding force on the train equal to that at 20 miles an hour, the pressure applied to the brake blocks at 50 miles an hour must be nearly two and a half times as great as that required at 20 miles an hour; and a still greater pressure is required for higher velocities.

Therefore, whilst a comparatively low pressure would make the wheels slide at low velocities, it was difficult to obtain any sufficient pressure to make the wheels slide at velocities over 60 miles an hour.

The figures given in the above tables must at present be accepted as only provisional, until an accurate mean has been obtained from the diagrams, which are not yet all worked out. But it may be assumed as an axiom that for high velocities a brake is of comparatively small value, unless it can bring to bear a high pressure upon the surface of the tyre almost instantaneously; and it should be so constructed that the pressure can be reduced in proportion as the speed of the train is reduced, so as to avoid the sliding of the wheels on the rails.

I must add that these experiments were made upon the London, Brighton, and South Coast Railway, who, through their General Manager, Mr. Knight, and Locomotive Engineer, Mr. Stroudley, gave every assistance in the construction of the van and the running of the train. The apparatus was mainly devised by Thomas Westinghouse, and constructed under his immediate supervision, and he assisted mainly in the experiments, &c. The earlier experiments were also made with the sanction of Mr. Horace Darwin.

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3. *On a Spectroscope of unusually large Aperture.** *By* G. J. Stoney.

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4. *On the Support of Spheroidal Drops and allied Phenomena.* *By* G. Johnstone Stoney, *M.A.*, *F.R.S.*, George F. Fitzgerald, *M.A.*, *F.T.C.D.*, *and* Richard J. Moss, *Keeper of the Minerals in the Museum of Science and Art, Dublin.*

The authors gave an account of several investigations and experiments† made by them during the past year upon the unequal stresses which arise in gas when polarised, that is, in which the molecular motions are not alike in all directions; and especially in the case where the polarisation arises from heat traversing the gas, as within radiometers, and in the gaseous layers which support spheroidal drops, those which protect the hand from a dangerous burn when dipped into melted metal, and many others. In such cases the molecular motions are not alike in all directions, and cause the stress within the gas directed across the layer to exceed the transverse stresses by an amount which may be called the Crookes's, or polarisation stress.

The investigation of this stress by a direct mechanical consideration of the molecular motions had been much facilitated by employing the conception of a

* The instrument was exhibited in the Chemical Laboratory of Trinity College.

† See the following memoirs:—'On some Remarkable Instances of Compressed Strata of Polarized Gas at Ordinary Atmospheric Tensions,' by G. Johnstone Stoney ('Scientific Proceedings of the Royal Dublin Society,' vol. i. p. 53, and 'Philos. Mag.' June, 1878, p. 457); 'On the Spheroidal State,' by Richd. J. Moss (do. vol. i. p. 83); 'On the Mechanical Theory of Polarization Stress in Gases,' by G. Johnstone Stoney ('Scientific Transactions of the Royal Dublin Society,' vol. i. Memoir 5); 'On the Mechanical Theory of Crookes's Force,' by George F. Fitzgerald (do. vol. i. Memoir 6).

tube placed across the layer, closed at the ends by patches of the heater and cooler, and with sides that reflect molecules by the same law that a polished surface reflects light. By employing this conception Mr. Stoney had shown that for small differences of temperature, and with a heater and cooler that are large, flat, parallel, and at a fixed distance asunder, the polarisation stress will vary nearly as

$$\frac{G^2}{PT}$$

where G is the flow of heat, P the tension of the gas, and T its temperature from absolute zero.

By a wholly different method, first suggested by Mr. Fitzgerald in a letter to 'Nature,' which consists in calculating the transverse stress in the same way as Clausius has calculated the stress across the layer, Mr. Stoney had obtained the following symbolical expression for the difference between these stresses, that is, for the polarisation stress,

$$\tfrac{1}{4}\rho\int_{-1}^{+1} I\overline{V^2}\,(3\mu^2-1)\,d\mu,$$

where μ is the cosine of the angle made by the path of a molecule with the normal to the layer, I the proportion of molecules moving at that angle, and V^2 the mean of the squares of their velocities.

By applying the same method of investigation to the general case of gas polarised in any way, Mr. Fitzgerald had obtained the expressions for the most general stresses that can arise, radial and tangential, and had shown them to be identical in form with the corresponding equations given by Maxwell in his electromagnetic theory of light.

And, finally, by attending to the conditions indicated by the theory, Mr. Moss had succeeded in keeping spheroidal drops in existence for upwards of an hour and a half, and had ascertained that spheroidal drops may be supported on air devoid of vapour. This last very important confirmation of the theory was established by experiments on melted paraffin at temperatures at which separate experiments had shown that no evaporation could be detected after a prolonged exposure of the paraffin in vacuo.

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5. *On the Cause of Travelling Motion of Spheroidal Drops. By* G. Johnstone Stoney, *M.A., F.R.S.*

In the course of the experiments referred to in the last communication a tendency in spheroidal drops to travel about over the surface of the liquid on which they rest had to be checked. This motion, where it was not simply due to convection currents in the supporting liquid, was traced to differences of surface tension, and may, by suitable arrangements, be made very swift. Thus, if spheroids of spirit of wine or ether be floated on a surface of warm water, the heavy vapour pouring down from the floating drops will, as is known, very much diminish the surface tension of the water wherever it comes in contact with it; and, as it cannot be made to pour down quite symmetrically all round, the drop finds itself on one side of the position of *minimum* tension, and is accordingly hurried along one radius of the rapid surface current which travels outwards in all directions from this point. The consequence is a very beautiful spectacle, the drops dashing about with an appearance of great sprightliness.

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6. *The Stanhope "Demonstrator," or Logical Machine.* By* Robert Harley.

* A model was exhibited. See 'Mind,' for April, 1878.

7. *Sur une nouvelle Méthode de Photographie Solaire et les Découvertes qu'elle donne touchant la véritable nature de la Photosphère.** *Par* Dr. J. Janssen.

M. Janssen expose devant l'auditoire des spécimens des photographies solaires qui sont obtenues à l'Observatoire de Meudon.

Ces spécimens comprennent:

1° Une contre-épreuve positive sur verre d'un cliché où l'image solaire a 30 centimètres de diamètre.

2° Des tirages sur papier, de grandissements qui donneraient à l'image solaire $1^m\ 50^c$ de diamètre.

3° Des tirages sur papier, de grandissements de clichés originaux à une échelle qui donnerait 4 mètres et demi de diamètre à l'image solaire.

Ces spécimens démontrent qu'on obtient actuellement à Meudon les détails de la granulation solaire comme les lunettes astronomiques ne pourraient les donner, résultat qui justifie ce que M. Janssen avait annoncé il y a une année environ, à savoir, qu'à l'égard du soleil, la photographie était un moyen tout nouveau de découvertes.

Les principes sur lesquels repose la méthode qui a permis d'atteindre ce résultat sont les suivants:

1° *Une plus grande perfection des procédés photographiques.*—Le collodion est sensibilisé avec des iodures et des bromures comme à l'ordinaire, mais le coton poudre doit être préparé à haute température pour donner une couche d'une finesse suffisante. Le développement se fait au fer, mais lentement, et on termine par un renforcement à l acide pyrogallique et au nitrate d'argent.

2° *L'augmentation des dimensions de l'image solaire* qui a été portée successivement de 10 à 12 centimètres de diamètre qui étaient les dimensions ordinaires, à 15, 20, 30, 40 centimètres et au-delà.

3° *L'achromatisme chimique de l'Objectif.*—Cet achromatisme a été calculé pour réunir en un faisceau, les rayons d'une région étroite du spectre situé près de G. M. Janssen a constaté en effet que dans les très courtes poses, ces rayons sont les seuls actifs. Cette condition est très importante pour la netteté des images solaires.

4° *Enfin la durée de la pose* qui a aussi une influence capitale sur le résultat. C'est en réduisant cette durée de $\frac{1}{2000}$ à $\frac{1}{4000}$ de seconde, qu'on a pu obtenir les granulations de la photosphère.

Comme il a déjà été annoncé, l'examen des photographies montre que la surface solaire est couverte d'une granulation générale. Les formes, les dimensions, la distribution de cette granulation ne sont pas en accord avec les idées qu'on s'était formées de ces éléments de la photosphère, d'après l'examen optique. Les images photographiques ne confirment nullement l'idée que la photosphère soit constituée par des éléments dont les formes constantes rappelleraient des feuilles de saule, des grains de riz, etc.

Ces formes qui peuvent se rencontrer accidentellement en tel ou tel point, ne sont que des exceptions, et ne peuvent être considérées comme exprimant une loi générale de la constitution du milieu photosphérique. Les images photographiques nous conduisent à des idées beaucoup plus simples et plus rationelles sur la constitution de la photosphère.

Formes des éléments granulaires.—Si l'on étudie la granulation dans les points où elle est le mieux formée, on voit que les grains ont des formes très variées, mais qui se rapportent plus ou moins à la forme sphérique. Cette forme est généralement d'autant mieux atteinte que les éléments sont plus petits. Dans les grains très nombreux, où les formes sont plus ou moins irrégulières, on voit que ces grains sont formés par l'agrégation d'éléments plus petits rappelant la sphère. Là même, où la granulation est moins nette et où les grains paraissent étirés, on sent que la sphère a été la forme première des éléments, forme plus ou moins modifiée par l'effet des forces qui agissent sur ce corps.

La forme normale des éléments granulaires de la photosphère parait donc se

* La communication était illustrée avec quelques grandes Photographies Solaires.

rapporter à la sphère, et les figures irrégulierès paraissent s'y rattacher encore, soit que l'élément ait été constitué par des corps plus petits, soit que ce même élément se trouve plus ou moins déformé par l'effet de forces étrangères agissant sur le milieu où il est plongé. Il résulte encore de ces considérations une conséquence très importante, c'est la preuve découlant du fait même de la grande variété des formes des éléments granulaires, que ces éléments sont constitués par une matière très mobile qui cède avec facilité aux actions extérieures. L'état liquide ou gazeux jouit de ces propriétés; mais en ayant égard à d'autres considérations que nous développerons plus tard, on est conduit à admettre pour les granulations un état très analogue à celui de nos nuages atmosphériques, c'est-à-dire à les considérer comme des corps constitués par une poussière de matière solide ou liquide nageant dans un milieu gazeux.

Origine des granulations.—Si la couche solaire qui forme la photosphère était dans un état de repos et d'équilibre parfait, il résulte de sa fluidité, qu'elle formerait une enveloppe continue autour du noyau solaire. Les éléments granulaires se confondraient les uns dans les autres, l'éclat du soleil serait uniforme dans toutes ses parties. Mais les courants gazeux ascendants ne permettent pas cet état d'équilibre parfait. Ces courants brisent et divisent cette couche fluide en un grand nombre de points pour se faire jour; de là la production de ces éléments qui ne sont que des fractions de l'enveloppe photosphérique. Ces éléments fractionnaires tendent à prendre la forme sphérique par la gravité propre de leurs parties constituantes; de là la forme globulaire qui, comme on voit, ne correspond pas à un état d'équilibre absolu, mais seulement relatif, celui où la matière photosphérique, ne pouvant se constituer en une couche continue, est divisée en éléments qui tendent à prendre individuellement leur figure d'équilibre. Mais cet état d'équilibre individuel des parties est lui-même assez rarement réalisé; en des points nombreux, les courants entraînent plus ou moins fortement les éléments granulaires, et leur forme globulaire d'équilibre est altérée, jusqu'à devenir tout-à-fait méconnaissable quand les mouvements deviennent plus violents.

Ces mouvements, dont la couche gazeuse où nagent les éléments photosphériques est incessamment agitée, ont des points d'élection. La surface solaire est ainsi divisée en régions de calme et d'activité relatives, d'où résulte la production du réseau photosphérique. En outre, dans les points mêmes de calme relatif, les mouvements du milieu photosphérique ne permettent pas aux éléments granulaires de se disposer en couchede niveau, d'où résulte l'enfoncement plus ou moins grand des grains au-dessous de la surface, et par suite, en égard au grand pouvoir absorbant du milieu où nagent ces éléments, la grande différence d'éclat des grains sur les images photographiques.

Ainsi, une première étude des nouvelles photographies nous conduit déjà à modifier beaucoup nos idées sur la photosphère, et l'ensemble des données qu'elles nous fournissent nous conduit à cette idée si simple sur la constitution des éléments photosphériques et sur les transformations qu'ils éprouvent par l'effet des forces auxquelles ils sont soumis.

Tirons encore cette conséquence du fait de la rareté relative des grains les plus brillants dans les images photographiques, que le pouvoir lumineux du soleil réside principalement dans un petit nombre de points de sa surface. En d'autres termes, si la surface solaire était couverte entièrement par les éléments granulaires les plus brillants qu'elle nous montre, son pouvoir lumineux serait. d'après une première approximation sur laquelle nous aurons à revenir, de dix à vingt fois plus considérable.

Il est encore une grande question sur laquelle les faits précédents jettent un jour nouveau: c'est la question si souvent débattue de la variation du pouvoir lumineux du soleil. Il est évident que les taches ne peuvent plus être considérées comme formant l'élément principal des variations que l'astre peut éprouver, et qu'il faudra désormais considérer le nombre et le pouvoir lumineux variable des éléments granulaires qui peuvent jouer ici un rôle prépondérant.

J'ajouterai enfin que l'étude des dernières photographies montre que la surface photosphérique est dans un état d'agitation extrême, que les éléments granulaires subissent les transformations les plus rapides à l'époque actuelle qui est cependant

celle d'un minimum de taches, ce qui tend à démontrer que l'activité solaire ne s'arrête jamais, mais qu'elle prend sensiblement des formes différentes pendant les périodes de maximum et de minimum.

M. Janssen se réserve de revenir sur la nature précise de ces mouvements des éléments de la surface photosphérique qui ont une si grande importance pour la constitution du soleil.

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8. *Sur la Constitution des Spectres Photographiques quand l'action lumineuse est extrêmement courte.* *Par* Dr. J. Janssen.

M. Janssen a constaté par des expériences nombreuses dont les premières remontent à 1874, que l'étendue du spectre photographique peut se réduire à une bande étroite située près de la ligne G (du côté du rouge) quand le temps de l'action lumineuse est très court.

M. Janssen montre à l'auditoire des spectres photographiques du soleil qui démontrent cette propriété. Une plaque notamment porte 7 spectres obtenus avec le même appareil et dans les mêmes conditions, sauf le temps de pose qui a été successivement de 5^m, 2^m, 1^m, 30^s, 15^s, 1^s. Le spectre correspondant à 5^m est très complet et s'étend de l'ultra violet à b dans le vert; les autres se rétrécissent successivement et celui de 1 seconde ne consiste qu'en une bande étroite de rayons un peu moins réfrangibles que G.

Ces expériences ont été faites avec des appareils en quartz et en spath.

On a étudié à ce point de vue les collodions sensibilisés avec les iodures et brômures de Potassium, Ammonium, Cadmium, Lithium, etc., employés isolément ou associés. Les spectres n'ont pas la même étendue pour ces diverses substances, mais le principe de la réduction à une bande subsiste toujours pour les poses très courtes.

Ainsi le principe dont il s'agit est général. Cette importante propriété a des conséquences théoriques et pratiques importantes. Relativement à ces dernières, il en résulte qu'on peut obtenir des images photographiques tolérables avec des lentilles pourvu que le temps de l'action lumineuse soit très court, ce qui est le cas pour le soleil. On voit de plus que l'achromatisme des objectifs photographiques peut être obtenu beaucoup plus rigoureusement que celui des objectifs pour la vision, puisque les rayons qu'on doit superposer n'appartiennent qu'à un point très limité de spectre.

La lunette photographique solaire de l'Observatoire de Meudon a été construite d'après ces principes.

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9. *Quelques remarques sur l'éclipse totale et la Couronne.* *Par* Dr. J. Janssen.

M. Janssen rappelle une idée émise dans son rapport sur l'éclipse de 1871, idée qu'il a développée au Congrès de Glasgow.

D'après cette idée la couronne étant formée au moins en grande partie par des gaz dans lesquels figure l'hydrogène, les jets protubérantiels qui dépassent la chromosphère, doivent augmenter l'importance de cette atmosphère coronale, et surtout doivent lui donner, avant qu'ils se soient dissipés, une apparence tourmentée et irrégulière.

Ces grandes colonnes hydrogénées peuvent expliquer les apparences de traînées lumineuses présentées si souvent par la couronne pendant les éclipses totales. Lorsque ces jets protubérantiels sont très nombreux et très puissants, ils doivent en outre troubler considérablement l'état statique du fluide coronal, et la couronne ne peut alors présenter l'aspect d'une atmosphère en équilibre. La constitution et l'aspect de la couronne doivent donc varier suivant la fréquence et l'importance des protubérances. A l'époque du maximum des jets protubérantiels, qui est à peu près celle du maximum des taches, l'atmosphère coronale doit, toutes choses égales d'ailleurs, présenter un aspect moins régulier, et révéler un état plus troublé.

Au contraire, à l'époque où les phénomènes extraphotosphériques se calment et présentent leur minimum d'action, le milieu coronal peut reprendre une figure relativement plus régulière et se rapprocher davantage des conditions d'une atmosphère en équilibre.

Si nous possédions des dessins très exacts de la figure de la couronne pendant les éclipses totales des derniers siècles, il serait bien intéressant de les étudier à ce point de vue.

Malheureusement les descriptions et les dessins que nous possédons ne sont généralement pas assez fidèles ni assez précis pour servir très utilement à cet objet.

Cependant on peut considérer comme confirmant l'idée émise, les observations précises de l'éclipse de 1842 analysées par Arago. On voit en effet que la couronne était alors formée d'anneaux concentriques nettement terminées, ce qui indique un état relatif d'équilibre. Or, l'année 1842 était une époque de minimum.

En 1871, la couronne présentait au contraire un aspect très tourmenté que j'ai décrit dans mon mémoire. Et cette année était une époque de maximum.

Ajoutons maintenant que la couronne pendant la dernière éclipse de Juillet 1878, d'après les premières relations publiées, aurait éte trouvée très basse et d'un aspect tout différent de celui de 1870 et 1871. Nous sommes encore dans la période minimum, puisque les taches solaires sont encore actuellement si rares, cette observation semble donc confirmer encore l'idée que nous avons émise dans le mémoire de 1871 et développée au Congrès de Glasgow.

Nous comptons revenir sur ce point, mais nous devons faire remarquer que si pour nous, l'aspect et la constitution de la couronne sont en dépendance avec les phénomènes protubérantiels, il ne faut pas oublier cependant que la couronne peut encore emprunter une partie de ses aspects à des matières cosmiques circulant autour du soleil dans ces régions, et venant compliquer ainsi les apparences de l'atmosphère coronale.

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10. *On a New Form of Receiving Instrument for Microphone. By* W. J. MILLAR, *C.E., Sec. Inst. Engineers and Shipbuilders in Scotland.*

The author, having been engaged in experiments upon the transmission of sound by wires without the aid of electricity or magnetism, had his attention more particularly directed to the connection between the strains produced in the bodies experimented upon and the sounds emitted. These experiments having been carried out with copper wires, it occurred to the author, after the announcement of the Microphone of Professor Hughes, that, since a magnetic needle, arranged as a galvanometer, has certain definite motions due to the flow of the electric current, then if the needle were *fixed*, instead of moving it would be thrown into a state of *strain*, and it would then give out sounds corresponding to the changing condition of the current. To test this, a few yards of covered copper wire were passed lengthwise, in galvanometer fashion, along a small bar magnet; sounds were immediately detected on breaking contact, when the magnet was pressed to the ear. These sounds were much re-inforced by placing the magnet against the shallow lid of a pasteboard box, or by placing it on a piece of tin.

A horse-shoe magnet with two or three yards of the same wire (about No. 30) laid lengthwise along one of its limbs, and with the lid of a tin box placed on the *flat sides* of the ends of the magnet, made an excellent receiver—speaking, singing, &c., being easily rendered audible.

A small form of receiver was exhibited by the author at the meeting, consisting of a bar magnet 3 inches long, $\frac{5}{16}$ inches broad, and about $\frac{5}{32}$ inches thick. About 6 yards of No. 30 covered copper wire are passed backwards and forwards lengthwise along the magnet, galvanometer fashion; the magnet is placed in a shallow pasteboard box, and a couple of pieces of tin are laid above and below the magnet (as this appeared to still further strengthen the sounds); the lid is then placed on, and the whole is thus rendered an easily portable pocket instrument. With this instrument, speaking, singing, whistling, besides other Microphone phenomena, are readily obtained. A single Leclanché cell, weakly charged, was used; a rough form of

microphone being used as transmittor, consisting of two pieces of carbon, touching slightly; one of the connecting wires resting over an upright pasteboard box into which the sounds were directed.

The author also stated that he had found that sounds could be obtained without a magnet, the receiver being simply a piece of tin around which a few yards of copper wire is wound. An arrangement of this kind was exhibited with which various microphone phenomena had been obtained; the sounds, however, being much reduced in loudness.

SATURDAY, AUGUST 17, 1878.

The Section did not meet.

MONDAY, AUGUST 19, 1878.

A Department of Mathematics was constituted.—See p. 457.

The following Papers were read in the General Section:—

1. *Report of the Committee on Atmospheric Electricity.*

See Reports, p. 103.

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2. *On Edmunds' Electrical Phonoscope. By* W. LADD.

An instrument for producing figures of light from vibrations of sound. It consists essentially of three parts—an induction coil, an interrupter, and a rotary vacuum tube.

The action of the instrument is as follows:—Sounds from the voice or other sources produce vibrations on the diaphragm of the interrupter, which being in the primary circuit of the induction coil, induce at each interruption a current in the secondary coil similar to the action of a contact-breaker or rheotome. Therefore each vibration is made visible as a flash in the vacuum tube. The tube revolving all the time at a constant speed, the flashes produce a symmetrical figure as the spokes of a wheel, or as in the Gassiot star. The number of spokes or radii are according to the number of vibrations in the interrupter during a revolution of the tube, and the number of vibrations being varied to any extent according to the sounds produced, the figures in the revolving tube will be varied accordingly. The same sounds always produce the same figures, providing the revolution be constant. In case of rhythmical interruptions being produced in a given sound, as in a trill, most beautiful effects are noticeable, owing to the omission of certain radii in regular positions in the figure.

The uses of this instrument are the rendering visible of sounds, and showing the vibrations required in their production, and is a mode of confirming by sight an appeal to the ear.

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3. *On Byrne's Compound Plate Pneumatic Battery. By* W. LADD.

This battery is the invention of Dr. Byrne, of Brooklyn, U.S.A. The chief features in this battery are a compound negative plate, and a simple mechanical means for preventing polarisation. The negative plate consists of the extreme negative element platinum, backed up by a plate of copper to reduce the resistance; the copper being protected by a thin sheet of lead, to prevent any local action that might occur owing to holes in the platinum, which would allow the exciting fluid to attack the copper, and a thicker sheet of lead on the back of the copper which is japanned. So a plate in section would show as consisting of, first, a sheet of platinum, then thin lead, then copper, and last, the thick japanned lead, the whole being soldered together to form a solid plate.

The batteries are built up with a zinc plate and two of the compound plates; the exciting fluid being a bichromate of potash and dilute sulphuric acid solution.

This battery would soon become polarised but for the injection of air between the plates, which action appears simply mechanical and not chemical, various gases producing no different effects.

When the air is pumped in, the most extraordinary effects may be produced, the "quantity" being much more than that of any other battery of the same size.

It is much used in the States for surgical operations, its extreme portability and control rendering it peculiarly useful in this direction.

The platinum loop can be raised to any temperature, and kept at the same simply by the action of the foot on the bellows, leaving both hands at liberty for operating, there also being an entire absence of fumes or other disagreeable smells.

A battery of four small cells will heat 9 inches of No. 16 platinum wire to redness.

4. *A Diagonal Eyepiece for certain Optical Experiments.* *By* Professor G. Forbes.

A diagonal eyepiece usually consists of a piece of plane unsilvered glass in the eyepiece, inclined at an angle of 45° to the axis of a telescope, so that light can be sent through the object-glass, while the telescope can still be used for direct vision. In experiments on the velocity of light, the light which has been thus sent out is itself examined through the telescope after reflection, and it is required to have this light as intense as possible. The diagonal glass must play two parts, which are in a certain sense contradictory. It must reflect as much light as possible through the telescope, and it must let as much as possible of the return light pass through to the eye. But at the time of emission the plane glass really allows only $\frac{1}{16}$th of the whole light to pass through, and on its return $\frac{15}{16}$ths are allowed to pass. Hence, on the whole, only $\frac{15}{16^2}$, or ·06, of the light is received. Fizeau and Cornu used double plane mirrors of microscope glass, thus doubling the reflection, and the latter found that he got ·16 of the whole light. But this increases the evil caused by defects in the transparency of the glass, the imperfection of the polish, and the presence of dust, which, however insensible in ordinary circumstances, produce a luminous field, which is very troublesome when powerful lights are used. To remedy this the author used a plane silver mirror, with a hole in the centre of such a size as to permit half of the light falling on the object-glass to pass through. In this way half of the light is sent out, and half of the return light illuminates the eye; so that we utilise ·25 of the light, and we have a perfectly dark field in the centre of the hole. This is theoretically four times as powerful as an unsilvered glass reflector, and practically the darkness of field makes it ten times as good.

5. *A Clock with Detached Train.* *By* Professor G. Forbes.

In the course of some experiments still progressing, the author has used a clock to give electric signals every second. It was made by E. Dent and Co., and has a train of only one wheel and one pinion. This clock only goes for one hour, but serves the purpose for which it was made. To make it go for a longer time, it was driven by a weight hung by a pulley on an endless chain in the usual way, and a common 5*s*. Swiss alarum clock was attached, which was connected with the chain, to wind it up continuously. This answers so well that a similar construction is suggested as not only the cheapest but also the best form of a clock with escapement. It consists of a pendulum and escapement with no train whatever, with an endless chain or thread passing over a pulley on the axis of the scape-wheel, and also over that of a secondary clock, hanging between them in a festoon which supports the weight by a pulley. The secondary clock gives the hours and minutes, and the clock without train shows the seconds. We thus have a clock without the errors introduced by a train. It is a gravity escapement without the locking friction.

6. *An Instrument for Indicating and Measuring the Fire-damp in Mines.** *By* Professor G. Forbes.

The instrument exhibited consists of a resonator of variable dimensions, and a tuning-fork of definite pitch. The resonator is a metal tube 1 inch in diameter

* 'Proceedings' R.S.E. 1878.

and 15 inches long, in which a piston slides so as to regulate the length of the tube. This tube is fixed in a block of wood, to which is attached a tuning-fork, whose points are just above the open end of the tube. The tuning-fork is sounded in any convenient way, and the piston is moved out and in, until the proper length is found, which is indicated by the resonator intensifying the sound of the tuning-fork. With practice the length can thus be determined with an accuracy of at least 1 in 250. But the length of resonator depends upon the density of the gas, a light gas requiring a longer resonator; and by reading off on a scale the position of the piston we judge of its density. In this manner 1 or 2 per cent. of fire-damp mixed with common air can be detected. Barometric pressure produces no difference. The temperature correction is made by reading off a thermometer of the proper dimensions in place of reading off a fixed mark on the piston. The only error is by the presence of dense carbonic acid gas. But carbonic acid gas tends to destroy the explosive character of fire-damp, and it appears that if the presence of carbonic acid prevented the instrument from indicating fire-damp it would certainly be sufficient to prevent the explosive character of the fire-damp.

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7. *On Certain Phenomena Accompanying Rainbows.** *By* Professor SILVANUS P. THOMPSON, *D.Sc.*, *B.A.*

The author narrated several instances of rainbows, seen chiefly in Switzerland, where radial streaks of light devoid of colour were observed within the primary and without the secondary bow. The explanation suggested was as follows: The wedge-shaped radial streaks are beams of sunlight, which become visible by diffuse reflection from particles of matter in their path, just as the apparently divergent beams of sunrise or sunset become visible. These "beams" being practically parallel to one another, appear to converge in the point exactly opposite the sun by perspective; or, in fact, just as the parallel beams of sunset appear divergent. Since the rainbow has for its centre the point opposite the sun, such beams must have positions radial with respect to the bow. They resemble, therefore, the *Rayons du Crépuscule* occasionally seen in the east at sunset. They had never been observed crossing the dark space between the primary and secondary bows. A similar phenomenon of rays might be sometimes seen in sunlight when the shadow of the observer fell upon a slightly turbid lake or river.

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8. *New Magnetic Figures.* *By* SILVANUS P. THOMPSON, *B.A.*, *D.Sc.*, *Professor of Experimental Physics in University College, Bristol.*

The author desires to draw the attention of the Section to the series of magnetic figures exhibited, which has recently been completed. The figures are permanently secured on glass by a process described in recent communications to the Physical Societies of London and Paris; and they have also been photographed as transparencies for the lantern.

It is believed that the figures assumed by iron filings in magnetic fields of many different kinds, in the series now produced, will be found of great use in the study and teaching of known laws of magnetic and electrodynamic action, and also in the experimental determination of the action of magneto-dynamic and electro-dynamic systems and machines. Faraday discovered that the lines of force traced out thus by iron filings possessed a significance hitherto disregarded, and revealed indeed the very seat of the attractions and repulsions taking place between magnetic bodies. The method had indeed been imperfectly employed by Musschenbröck at an earlier date, but it only became really fruitful in the hands of Faraday. The author has applied Faraday's reasoning to the figures produced by

* 'Philosophical Magazine,' October 1878.

electric currents traversing conductors in various circumstances, and finds that from the figures alone nearly all the recognised electrodynamic, magneto-dynamic and magneto-electric relations can be deduced or verified.

The series of figures now presented illustrate amongst other matters the following actions:—

(1.) The attraction (or repulsion) of magnets by magnets.
(2.) The attraction (or repulsion) of currents by currents.
(3.) The attraction (or repulsion) of magnets by currents.
(4.) The rotation of magnets by currents.
(5.) The rotation of currents by magnets.
(6.) The rotation of a magnet round its own axis under the influence of a current.
(7.) The repulsion by a current of its own parts.
(8.) The mutual inductive action of solenoids and magnets, and of magnets and magnetic matter.
(9.) The flow of currents in conductors and conducting media.
(10.) The action on magnets of magnetic media.
(11.) The action of magnetic instruments, magnetometer, galvanometer, electro-dynamometer.
(12.) The action of magneto-electro machines.
(13.) The magnetic properties of cobalt and nickel.

The figure illustrative of the lines of force surrounding a current has been previously given by Faraday, Guthrie, and Barrett. Those illustrative of the attraction and repulsion of parallel currents by Faraday, but imperfectly. Those illustrative of flow of currents in conductors by Kirchhoff, Guthrie, and Carey Foster and Lodge. Those illustrating the action of the galvanometer and the Gramme machine were suggested to me respectively by Mr. C. W. Cooke and Mons. A. Niaudet. The photographs have been executed directly from the filing-figures by Mr. Robert Gillo, of Bridgwater, of the firm of F. York and Co., of Notting Hill, the eminent manufacturers of photographic transparencies for the lantern.

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9. *On Dimensional Equations, and on some Verbal Expressions in Numerical Science. By* Professor JAMES THOMSON, *LL.D., D.Sc., F.R.S.*

In recent years attention has been given, more than before, to relations among standard quantities of variable things, to be taken as units for use in giving numerical expression to various quantities of those things. The quantity of each different variable thing selected as a unit might be, and often has been, arbitrarily chosen, independently of the quantities chosen for units of other things. But great advantages as to convenience and facility are attainable by making a methodical connection among the quantities to be selected for the units of the various things, so that when some of the units are arbitrarily selected, the others will be derived from them in some good systematic way.

The units thus arbitrarily selected are called *fundamental units;* and the others obtainable from them by the systematic method are called *derived units.*

Teaching on this subject is given in the early pages of Professor Clerk Maxwell's 'Treatise on Electricity and Magnetism,' and in Professor Everett's 'Treatise on the Centimetre-Gramme-Second System of Units.' The subject is important; but much of the nomenclature and notation hitherto used is very confusing and unsatisfactory.

I now wish to propose some amendments, or new modes of expression, which appear to be commendable.

Instead of saying, as is done in Professor Everett's very useful treatise,

"The unit of acceleration varies directly as the unit of length, and inversely as the square of the unit of time;"

I would propose to say

The change-ratio of the unit of acceleration is the product of the change-ratio of the unit of length and the inverse second power of the change-ratio of the unit of time.

The meaning of the new name, *change-ratio*, may be given by the following definition.

DEFINITION.—In respect to changes of any variable, the *change-ratio* is the ratio of the new value to the old, for any change from one value of that variable to another.

Further, in Everett's treatise, the relation already referred to among the units of *length, time*, and *acceleration*, is stated in some other ways, which I will next cite:—

"The dimensions of acceleration are $\frac{\text{length}}{(\text{time})^2}$."

"The dimensions of the unit of acceleration are $\frac{\text{unit of length}}{(\text{unit of time})^2}$."

Instead of either of these, I would substitute this—

$$\text{Change-ratio of unit of acceleration} = \frac{\text{change-ratio of unit of length}}{(\text{change-ratio of unit of time})^2}.$$

This expression states clearly and correctly all the truth which is meant to be conveyed by the previous statements.

In order now to be enabled to speak, in language brief and free from ambiguity, of any numerical expression whatever, whether whole or fractional, greater or less than unity, or unity itself, I shall use the word *numeric*, which I recommend for general use, to comprise all the meanings which at present are conveyed in common use, but with much of troublesome ambiguity, by words or phrases such as *number, fraction, number or fraction, number and fraction, number or proper fraction or improper fraction.* I recommend that, as soon as possible, the word number should be restricted to its only proper signification, which is often at present designated in an objectionable way by the two words "*whole number*," but which is often also expressed, and really properly so, by the single word *number.**

Now we have no right to speak of dividing one quantity by another of a dissimilar kind, except, merely for brevity, in the case of dividing the numeric expressing the one quantity by the numeric expressing the other quantity, after we have fixed upon units of the two things. Thus we have no right to speak of *unit of length* divided by *unit of time*, nor to employ, unless perhaps for brevity, and under an implied protest, such a notation as

$$\frac{\text{Unit of length}}{\text{Unit of time}}.$$

Further, we have no right to speak of "*second power of unit of time*," nor of "*square of unit of time*." The name *power* seems admirably well suited (whether by deliberate design entirely, or partly by good chances) for its uses in reference to what are called powers, whether integral or fractional, of any numerics, as for instance

$$x^2, x^3, x^{\frac{1}{2}}, x^{2.13}. \&c., \&c.;$$

* Thus, for instance, in the public regulations for Post Office Savings Banks, issued by authority of the Postmaster-General ('British Postal Guide'), the intimation is made that "*At these banks deposits of one shilling, or any number of shillings, will be received*," this being, however, subject to some restrictions, which need not be mentioned here, merely assigning limits to the amounts that will be accepted from any one person. Now the words here quoted would convey a false statement of what the Post Office authorities really mean to announce, if the word "number" were allowed to mean a fractional numerical expression. The announcement is obviously framed on the presumption that the word "number" in it can only mean *legally* what in the present paper is referred to as its only *proper* signification, that, namely, which is commonly designated as "*a whole number*" or "*an integer*." If an intending depositor, understanding the word "number" in the extended sense in which it is very often, and also quite authoritatively used, would offer a deposit of $7\frac{1}{3}$*s*., his offer would be refused, as it would amount to 7*s*. 4*d*., which is not contemplated in the regulations as an amount to be accepted as a deposit.

More examples to the same effect might be cited from usages in practical business affairs; and also from usages of scientific writers in arithmetic and in other branches of mathematics, but the one here given may suffice.

and also for its uses in cases such as

$$x^{-2},\ x^{-3},\ x^{-\frac{3}{4}},\ x^{-2.13},\ \&c., \&c.;$$

in any of which x may denote any numeric whole or fractional.

Such expressions as the *square of the unit of time* are not to be approved of. That expression, for instance, is too like such combinations of words as *a square second*, or *a square minute*. It is not really quite so unreasonable, however, because there is a good meaning sometimes intended though badly expressed, when the *square of the unit of time* is spoken of, that unit being then regarded as a variable, and the true meaning being usually just what may be distinctly stated as *the second power* of the *change-ratio of the unit of time*. A second is essentially a constant quantity of time; and *the square of a second, a second squared*, and *the second power of a second of time*, are all of them essentially meaningless conjunctions of words.

It is to be observed that any ratio is a numeric, or may be treated as such to any degree of approximation we please; and so we can have the second power or any other power of a change ratio; and we are entitled properly to write as a fraction any power of any change-ratio divided by any power of the same or of any other change-ratio. That fraction will be itself a numeric, and may properly form one side of an equation having a numeric for its other side.

It follows, then, under the views already offered, as to legitimate and illegitimate modes of expression and notation, that such notations as

$$1\frac{\text{yard}}{(\text{minute})^2}=\frac{1}{1200}\frac{\text{foot}}{(\text{second})^2},$$

which is given in Dr. Everett's Treatise (page 4), as a very expressive notation now becoming common, are not commendable, and are such as it is desirable promptly to reject. We might quite rightly note that

$$1\frac{\text{yard}}{\text{foot}}=\frac{1}{1200}\left(\frac{\text{minute}}{\text{second}}\right)^2,$$

but it would be illegitimate to pass from this, by imitation of a real algebraic process, so as to write

$$1\frac{\text{yard}}{\text{foot}}=\frac{1}{1200}\frac{(\text{minute})^2}{(\text{second})^2},$$

and thence further to make a pseudo-multiplication of both sides by foot, and a pseudo-division of both sides by (minute)^2, and so to bring out the seeming equation above objected to.

The name *dimensions of units* is subject to a distressing ambiguity. It might mean the *greatness* or *smallness* of them; and indeed a dimensional equation is for the very purpose of telling how the *greatness* of some units changes in accordance with changes made in the *greatness* of other units. This is not, however, the idea which is attached to the word *dimensions* in *dimensional equations*. It is mentally associated rather with such notions as the three dimensions in space, length, breadth, and thickness (not to say also with the fanciful notions, so often now put forward, of a fourth dimension in space, or a $2\frac{1}{2}$th, or $4\frac{3}{5}$th, or an infinite number of other alleged dimensions in a dreamland space, not found in our world or conceived in our brain). It has, in fact, to do with change-ratios, or powers of change-ratios of quantitative units, whereby the magnitudes of the various units are mutually connected, and some of them specified by reference to others. There is, I may remark, for instance, in Dr. Everett's book, one article on *Dimensions of Units*, and another on *Dimensions of the Earth*. Now the word *dimensions* in these two cases has totally different meanings.

10. *On Lead and Platinised Lead as a Substitute for Carbon and Platinised Silver, in Leclanché, Bichromate, and Smee's Batteries.* By EDWARD T. HARDMAN, *F.C.S., &c.*

The chief objections to carbon as a positive plate are: (1) the difficulty of preparation; (2) the limited size of the plates; (3) their brittleness; and (4) the

difficulty of ensuring perfect connection. As to the last, it often occurs that the exciting solution makes its way upwards through the porous carbon and gradually destroys the metallic connections, except when the cell has been very carefully constructed. Inconveniences like this in a Leclanché electric bell battery induced the author to substitute pieces of gas-pipe for the carbon, and this answered admirably for months. The addition of a little hydrochloric acid occasionally to the exciting solution of ammonium chloride being necessary.

Double fluid Bichromate Battery.—Ordinary sheet-lead is an effective substitute for carbon in this battery. Like all bichromate batteries, it is not constant, requiring frequent renewal of the bichromate. The lead is practically unaffected.

Platinised Lead, Single Fluid Bichromate, and Smee's Batteries.—Unprepared lead is tolerably effective for the ordinary bichromate battery, but its power is enormously increased when the surfaces are roughened, and thinly coated with platinum. A single cell with plates about 3 inches by 4 inches will heat 4 inches of platinum wire of about 20 gauge, and fuses the hair-like platinum wire used sometimes to explode gunpowder.

It is equally effective as a Smee battery. The results appear to be quite as powerful. It answers capitally for working medical coils. The platinising is readily effected by a process described by the author.*

In conclusion, the author points out that large batteries can be thus constructed very cheaply by any amateur, and that the size of the cell is almost unlimited, as it is easy to get any sized sheet of lead; while with carbon cells of large size the plates require a multiplicity of connections.

It is recommended to withdraw both plates from the exciting solution when out of use. After being immersed some months, the platinum coating seems to suffer a little, but can be easily renewed.

Platinised lead has been recommended for Grove's battery by Callan,† but has, I believe, never been tried in the forms I have mentioned.

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11. *On a New Form of Electro-Registering Apparatus.* By Denny Lane.

In many forms of registering apparatus the friction of the tracing point upon the paper is so great that it cannot be overcome by the motive force of the index of the instrument to be registered. It is proposed to move the registering pencil by independent mechanism actuating an arm which is always kept parallel with the index. The index is placed between two small screws on the independent arm, the ends of which are so placed as to be distant $\frac{1}{1000}$ of an inch from the index, while the latter is exactly parallel with the registering arm. A voltaic current enters the index, and so long as both arms are exactly parallel no current can pass to either screw. If, however, the index moves $\frac{1}{1000}$ of an inch, it touches one or other of the screws, and the current is completed to one or other of two electro-magnets. This electro-magnet attracts an armature which releases the detent of a fly train. The train coming into action shifts the registering arm until it becomes again parallel with the index, when the current ceases and the detent again holds the train. By this mode the registering arm is always maintained parallel with the index, and consequently the pencil which it carries registers the position of the index; but the motive power is derived from the springs or weights of the fly train. The only work which the index has to do is to make contact with one or other of the two screws.

Instead of wheel trains, hydraulic or pneumatic apparatus may be employed to raise or lower the registering arm, the operation of each being controlled by inlet and outlet valves wrought by the armatures of electro-magnets.

Unlike the photographic registrations, these can be seen at once, and the delay

* The lead being cleaned with rough emery paper, and well roughened by a file, is brushed over with bichloride of platinum.

† Ann. Ch. Phys. (3) viii. 28; also Watts's Chem. Dict. ii. 426.

and trouble incident to the preparation and development of sensitive papers are avoided.

The system can also be applied to the regulation of clocks driven by revolving pendulum or other continuous motion. The index hand may be moved by an oscillating pendulum, and the independent hand moved by a revolving pendulum. If the revolving pendulum train goes too slow, contact is made and the current can be made to diminish friction on a revolving disc; and if the train goes too fast, the friction can be increased by the current until the two movements become isochronous. In fact, any angular or rectilineal movement can be repeated with any required force without imposing any sensible friction on the originating apparatus.

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12. *On an Isochronic Pendulum.* By Denny Lane.

Every dynamic effect can be expressed by three factors—weight, space, and time. If successive events can be made exactly similar, they must occupy the same time, and time can be measured by counting the number of such events.

The oscillations of a pendulum are the events that are most generally employed for this purpose, but the successive events are not exactly similar, in consequence of variations of five kinds:—

1. Variation in temperature causing change in length of pendulum.
2. Variation in density of the air in which pendulum moves.
3. Ditto in viscidity of the air.
4. Change in arc of oscillation.
5. Change in impulse given in order to maintain arc.

It has been the habit hitherto to introduce compensations in order to counterbalance these variations, or some of them. I propose, instead of compensating for variations after they have arisen, to prevent the variations from occurring, or at least to confine them within limits so narrow that they shall not affect the time of the oscillation.

1st. To prevent variations of temperature the pendulum is enclosed in a case which is kept at a constant temperature, the case being surrounded by a fluid kept always at the same heat by a thermostat. This thermostat is a vessel filled with an expansible liquid, like alcohol, which by variation in volume raises or depresses mercury contained in a bent tube. The upper surface of the mercury in one leg of the bent tube acts as a valve to increase or diminish the supply of coal-gas to a burner, and maintains at a constant temperature the fluid surrounding the pendulum case, and therefore the pendulum itself. Thus variation in heat is prevented.

2nd. The pendulum case is hermetically sealed, the sides being rigid, and thus any change in the pressure of the air contained is prevented.

3rd. The air remaining at the same temperature and pressure, any variation in its viscidity is prevented.

4th. All the retarding forces being equal, the arc must be equal if the impulse given to maintain the arc remains constant.

5th. The impulse is given to the pendulum by the intermittent action of an electro-magnet, which is active as the pendulum descends, but loses its magnetism as the pendulum rises. This impulse should remain the same if the current which produces it remains the same, and this can be effected in three different ways. Every electric current depending directly on the electro-motive force, and inversely on the resistance, if the electro-motive force and the resistance remain the same or retain the same ratio, the current is constant.

(*a*) It is proposed to maintain the current the same by a vibrating regulator, consisting of an adjustable armature, attached to a balance, and placed above an electro-magnet included in the main circuit. As the current passes it attracts the armature, which, as soon as the current ceases, is again drawn away by the action of a counterpoise on the other end of balance. The intermittent current, therefore, keeps the balance in vibration until the current falls below a certain fixed point, when the vibration ceases. So long as the vibration lasts, a small funnel attached

to the vibrator diverts from a regulating cell of the battery a minute stream of exciting fluid; but if the vibration ceases this small stream passes on to the battery, and so increases its power until the vibrator is again set in motion and diverts the exciting fluid. Thus the current is continually restored to the right point, and the impulse continues to be the same.

(*b*) If the electro-motive force varies, the current can be maintained constant by causing the resistance to vary in the same ratio. This can be effected by a very light pendulum, having the same period as the main pendulum. Any variation in the current will change the arc of the light pendulum, before the heavy pendulum is sensibly affected, and this variation of arc can be made to vary the resistance in a solid or fluid portion of the current.

Two vibrators may be employed, with counterpoises slightly different. If the current is in the normal state, the light vibrator acts, but not the heavy one. If the current be too strong, both vibrators act; if too weak, neither. The action of both may be made to introduce resistance or diminish electro-motive force. The inaction of both may diminish resistance or increase electro-motive force, so as to restore the current to its normal condition.

(*c*) The variations of the arc can be confined within very narrow limits by the following contrivance. A permanent magnet attached to a pendulum, by its attraction for two small magnets attached to a balance or unstable equilibrium, causes the latter to oscillate so as to make contact when the pendulum is at the extremity, and break contact when at the middle of the arc; the current so opened passes through an electro-magnet placed below the pendulum, which terminates in an armature. The current being made slightly stronger than is necessary for a given arc, its oscillation increases until the permanent magnet attached to it brings into action a balance similar to the former, but placed somewhat further from the centre of oscillation. The action of the balance opens a second path for the current, which is thus shunted from the electro-magnet, diminishes the impulse given by the latter, and so reduces the arc again.

It is, therefore, concluded that if by any of the modes above mentioned, or any other system of rheostal, the current be maintained constant, the impulses will be equal, and the arc must be constant; or, again, if the variation of the arc be kept within very narrow limits, the time of oscillation will remain constant, and the pendulum will remain isochronic.

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13. *The Temperature of the Earth Within.* *By* WILLIAM MORRIS.

The state of this question amounts to this: that we know, nor, *by the methods hitherto pursued*, can ascertain absolutely nothing of the heat of the earth within.*

The following is a method to ascertain the temperature of the earth within, and, furthermore, to establish a permanent system of observation on the temperature and electric state:—

Place one of two suitable *uncompensated* chronometers (provisionally so-called) at the bottom of a (special) bore. This chronometer is to be *actuated* from surface apparatus *electrically*, so as in its inaccessible, buried position, to be maintained permanently in motion, and in turn to control *electrically* a clock at the surface which will indicate to an observer the *time* (that is, revolutions in given time), kept below; being susceptible to temperature, the movements of this chronometer will be inter-dependent with the temperature below. The second of the pair, placed on the observatory wall, with a standard thermometer hanging by it, will indicate *time* (revolutions in given time) inter-dependent with the *known temperature* of the observatory. *Knowing the temperature of the observatory*, and comparing the inter-dependent *time* registered by the observatory chronometer with that of the chronometer at the bore-bottom as represented by the clock electrically controlled therefrom, we can tell readily whether the temperature of the observatory is higher or lower than that affecting the buried chronometer.

The electric cables can be used to lower the chronometer into the bore.

* See 'Nature,' No. 447, vol. xviii. May 23, 1878.

To render the chronometer at the bottom of the bore susceptible only to the influence of the *temperature within*: ram over it suitable material, as over gunpowder in rock-blasting operations, so as to exclude water and air.

Sets of apparatus may be arranged to investigate the temperatures at various depths.

Observation stations.—Bores in the deeper rocks will give results of greater value respecting the general conditions of the earth within. Bores in the higher strata will give results interesting chiefly as compared with those from the deeper rocks, and *in connection with the phenomena of earthquakes and volcanos.* Stations in insular and continental, below and above sea level, and in different geological systems, should be chosen.*

14. *On Sunspots and Rainfall. By* C. MELDRUM. Ordered by the Council to be printed *in extenso* among the Reports, see p. 230.

15. *On Lightning Conductors. By* R. ANDERSON.

The following Papers were read in the Department of Mathematics:—

1. *Report of the Committee on Babbage's Analytical Engine.* See Reports, p. 92.

2. *Report of the Committee on Mathematical Tables, with an Explanation of the Mode of Formation of the Factor Table for the Fourth Million.* See Reports, p. 172.

3. *On a New Form of Tangential Equation.*† *By* JOHN CASEY, *LL.D., F.R.S., M.R.I.A., Professor of Mathematics in the Catholic University of Ireland.*

1. The tangential equation of a curve is a relation among the co-efficients in the equation of a variable line, which being fulfilled the line must be a tangent to the curve. Thus, let O be the origin, OX, OY the axes, and let a variable line MN, in any of its positions, make an angle ϕ with OX, and an intercept ν on it, then the equation of MN is

$$x + y \cot \phi - \nu = o.$$

From this it follows that if ν and ϕ be given, the position of the line is fixed, and also that any relation between ν and ϕ such as

$$\nu = f(\phi),$$

will be the tangential equation of a curve which is the envelope of the line.

This form is remarkable for the facility with which it can be transformed into all the known forms of equation, and also for the simplicity of the formulæ which it gives for metric purposes, such as rectification, curvature, &c.

We give here an outline of the transformations, &c., of which it is capable.

2. The tangential equation $\nu = f(\phi)$ of a curve being given to find its Cartesian equation.

* The original paper was read *in extenso* at the sitting of the Academy of Sciences, Paris, on the 16th September.

† This paper was published *in extenso* in the 'Philosophical Transactions' for the year 1878, vol. 167, part 2.

Since the equation of the line is

$$x + y \cot \phi - f(\phi) = o. \tag{1}$$

Differentiating with respect to ϕ we get

$$y = -f'(\phi) \sin^2\phi; \tag{2}$$

hence from (1) we get

$$x = f(\phi) + f'(\phi) \sin\phi \cos\phi, \tag{3}$$

and eliminating ϕ between (2) and (3) we have the Cartesian equation required.

Thus, if a line of constant length slide along two rectangular lines, we have

$$\nu = a \cos\phi \therefore f(\phi) = a \cos\phi.$$

Hence from (2) and (3)

$$y = a \sin^3\phi,\ x = a \cos^3\phi$$
$$\therefore x^{\frac{2}{3}} + y^{\frac{2}{3}} = a^{\frac{2}{3}}.$$

3. If we differentiate the values of x and y in equations (2) and (3) we get by squaring and adding, &c.,

$$\frac{ds}{d\phi} = 2f'(\phi) \cos\phi + f''(\phi) \sin\phi,$$

Which may be written

$$\frac{ds}{d\phi} = \frac{\frac{d}{d\phi}\left(f'(\phi) \sin^2\phi\right)}{\sin\phi}. \tag{4}$$

Thus the equation of the evolute of an ellipse is

$$\nu = \frac{c^2}{\sqrt{a^2 + b^2 \tan^2\phi}}.$$

Hence, from equation (4) we get, putting

$$\Delta(\phi) = \sqrt{1 - e^2 \sin^2\phi}$$

$$s = \frac{b^2}{a} \cdot \frac{1}{\Delta^3(\phi)}. \tag{5}$$

Which is the intrinsic equation of the evolute of an ellipse.

4. From formula (4) we can find conversely the tangential equation from the intrinsic.

Thus, let $S = F(\phi)$ be the intrinsic equation, and then we have from equation (4)

$$\frac{d}{d\phi}\left(f'(\phi) \sin^2\phi\right) = F^1(\phi) \sin\phi$$

$$\therefore f(\phi) = \int \operatorname{cosec}^2\phi \left\{\int F'(\phi) \sin\phi d\phi\right\} d\phi. \tag{6}$$

For example, the intrinsic equation of the evolute of the catenary is

$$s = c\int \tan\phi d\phi$$

$$\therefore F(\phi) = c\int \tan\phi d\phi.$$

Hence by formula (6) we get the tangential equation of the evolute

$$\nu = c\ \frac{\left\{1 - \log\left(\sec\phi + \tan\phi\right)\right\}}{\tan\phi}. \tag{7}$$

5. Let the tangential equation of a curve be $\nu = f(\phi)$, then, denoting the radius of curvature by ρ, we have from equation (4)

$$\rho \sin\phi = \frac{d}{d\phi}\left(f'(\phi) \sin^2\phi\right), \tag{8}$$

and, therefore, the intrinsic equation of the evolute is

$$s \sin\phi = \frac{d}{d\phi}\Big(f'(\phi)\sin^2\phi\Big). \tag{9}$$

6. If the tangential equation of a curve be given, we find the tangential equation of its evolute by equations (6) and (9). For if $\nu = f(\phi)$ be the tangential equation, the intrinsic equation of the evolute is

$$s = 2f'(\phi)\cos\phi + f''(\phi)\sin\phi;$$

let this be denoted by $F(\phi)$ and by art (4), the tangential equation is given by equation (6).

Now from the value of $F(\phi)$ we get

$$F'(\phi)\sin\phi = 3f''(\phi)\sin\phi\cos\phi + f'''(\phi)\sin^2 - 2f'(\phi)\sin^2\phi.$$

Hence we get

$$\int \operatorname{cosec}^2\phi\left\{\int F'(\phi)\sin\phi d\phi\right\}d\phi = f'(\phi) + f(\phi)\cot\phi$$

$$\therefore\ \nu = f'(\phi) + f(\phi)\cot\phi,$$

$$\text{or } \nu = \frac{\frac{d}{d\phi}\Big(f(\phi)\sin\phi\Big)}{\sin\phi}, \tag{10}$$

is the tangential equation of the evolute.

Hence it follows that if ν_1, ν_2, ν_3, &c., denote for the successive evolutes what ν denotes for the curve itself, that

$$\nu_1\sin\phi = \frac{d}{d\phi}\Big(V\sin\phi\Big)$$

$$\nu_2\sin\phi = \frac{d_2}{d\phi_2}\Big(V\sin\phi\Big),$$

and in general

$$\nu_n\sin\phi = \left(\frac{d}{d\phi}\right)^n(V\sin\phi). \tag{11}$$

7. From the preceding article it is easily seen that we have for the n^{th} involute

$$\underset{-n}{\nu}\sin\phi = \iiint_{d\phi}^{\cdots n}\Big(f(\phi)\sin\phi\Big), \tag{12}$$

or if we interpret symbols of differentiation with negative indices as denoting integration, the formula (11) includes both evolutes and involutes, according as n is regarded positive or negative.

8. From the tangential equation of a curve we get the intrinsic equation of the involute. Thus let $\nu = F(\phi)$ be the tangential equation of the involute, then we have from equation (4)

$$\frac{ds}{d\phi} = \frac{d}{d\phi}\left(\frac{F'(\phi)\sin^2\phi}{\sin\phi}\right),$$

and from equation (12) we have

$$F(\phi) = \frac{\int f(\phi)\sin\phi\, d\phi}{\sin\phi}$$

$$\therefore\ \frac{ds}{d\phi} = \frac{d}{d\phi}\Big(f(\phi)\sin\phi\Big) + \int\Big(f(\phi)\sin\phi\, d\phi\Big)$$

$$\therefore\ s = f(\phi)\sin + \iint\Big(f(\phi)\sin\phi\, d\phi\Big)d\phi,$$

or, as it may be written,

$$s = \left\{1 + \left(\frac{d}{d\phi}\right)^{-2}\right\}f(\phi)\sin\phi. \tag{13}$$

Hence, if $\nu = f(\phi)$ be the tangential equation of a curve, the intrinsic equation of its involute is

$$s = \left\{(1 + \left(\frac{d}{d\phi}\right)^{-2}\right\} f(\phi) \sin\phi\,;$$

or, since s is the length of the involute,

$\frac{ds}{d\phi}$ is the length of the given curve.

Hence, if $\nu = f(\phi)$ be the tangential equation of a curve, the length of the curve is

$$\left\{\frac{d}{d\phi} + \frac{d}{d\phi}^{-1}\right\} f(\phi) \sin\phi. \tag{14}$$

SECTION II.

PEDALS.

9. If we make the axis of y the initial line, it is evident that the polar equation the first positive pedal of the curve

$$\nu = f(\phi)$$

is

$$\rho = f(\phi) \sin\phi. \tag{15}$$

Hence the tangential equation of any curve is transformed into the polar equation of its first positive pedal by changing ν into ρ and multiplying the function on the right-hand side by $\sin\phi$.

Thus the tangential equation of the parabola is $\nu = a \tan\phi$.

Hence its first positive pedal is

$$\rho = a \sin^2\phi \sec\phi.$$

10. The tangential equation of the evolute of $\nu = f(\phi)$ is

$$\nu = f(\phi) \cot\phi + f(\phi)^1.$$

Hence the polar equation of the first pedal of the evolute is

$$\rho = \frac{d}{d\phi}\Big(f(\phi) \sin\phi\Big). \tag{16}$$

This also appears from equation (11).

And the polar equation of the first pedal of the n^{th} evolute is

$$\rho_n = \left(\frac{d}{d\phi}\right)^n f(\phi) \sin\phi\,; \tag{17}$$

and by supposing n negative we have the first positive pedal of the n^{th} involute.

11. By reversing the reasoning in art. 9 we have the following theorem:—

If $\rho = \mathrm{F}(\phi)$ be the polar equation of a curve, the tangential equation of its first negative pedal is

$$\nu = \frac{\mathrm{F}(\phi)}{\sin\phi}. \tag{18}$$

Hence the tangential equation of the first negative pedal of a conic section from any point in its plane is

$$(a \cos^2\phi + 2b \sin\phi \cos\phi + b \sin^2\phi)\nu^2 \sin^2\phi$$
$$+ 2(g \cos\phi + f \sin\phi)\nu \sin\phi + c = o.$$

12. The equation of the line whose envelope is the negative pedal is

$$x \sin\phi + y \cos\phi - \mathrm{F}(\phi) = o. \tag{19}$$

Hence the negative pedal is the result of eliminating ϕ from the equations

$$x = (\phi) \sin\phi + \mathrm{F}'(\phi) \cos\phi,$$
$$y = \mathrm{F}(\phi) \cos\phi - \mathrm{F}'(\phi) \sin\phi.$$

From these equations we get

$$s = \mathrm{F}'(\phi) + \int \mathrm{F}(\phi) d\phi \tag{20}$$

13. If we substitute $\dfrac{\mathrm{F}(\phi)}{\sin\phi}$ for $f(\phi)$ in art. (5), equation (9), we get

$$s = \left\{1 + \left(\frac{d}{d\phi}\right)^2\right\} \mathrm{F}(\phi).$$

Hence, if $\rho = \mathrm{F}(\phi)$ be the polar equation of a curve, the intrinsic equation of the evolute of its first negative pedal is

$$s = \left\{1 + \left(\frac{d}{d\phi}\right)^2\right\} \mathrm{F}(\phi).$$

In like manner, from art. (8) the intrinsic equation of the involute of its negative pedal is

$$s = \left\{1 + \left(\frac{d}{d\phi}\right)^{-2}\right\} \mathrm{F}(\phi).$$

PARALLEL CURVES.

14. If $\nu = f\phi$ be the tangential equation of a curve, we have at once the tangential equation of a parallel curve at the distance k given by the equation

$$\nu = f\phi \pm k \operatorname{cosec} \phi. \tag{21}$$

This equation enables us to write out at once the equation of the reciprocal of the parallel curve, which is evidently the curve whose polar equation is

$$\frac{r^2}{\rho} = f(\phi) \sin \phi \pm k,$$

Where γ is the radius of the circle of reciprocation. Thus the equation of the reciprocal of the parallel to the ellipse

$$\nu = \sqrt{a^4 + b^4 \cot^4 \phi}.$$

is $$\frac{r^2}{\rho} = \sqrt{(a^2 \sin^2 \phi + b^2 \cos^2\phi} \pm k.$$

or in Cartesian co-ordinates

$$4r^4k^2 \, (x^2 + y^2) = (a^2x^2) + - k^2(x^2 + y^2)^2 r^4. \tag{22}$$

SECTION III.

Rectification of Bicircular Quartics.

(15.) Being given a conic F (called the *focal conic*) and a circle J (called the *circle of inversion*), it is known that a bicircular quartic is the envelope of a variable circle whose centre moves on F, and which cuts J orthogonally. It is proved in my memoir on "Bicircular Quartics" that there is a fourfold generation of the curve, viz., there are four focal conics, F, F′, F″, F‴, and these are confocal, and the corresponding circles of inversion J, J′, J″, J‴, are mutually orthogonal. The rectification of the quartic depends on the following geometrical theorem. In a bicircular quartic there exists a series of inscribed quadrilaterals ABCD, whereof the sides AB, BC, CD, DA pass through the centres of the four circles J, J′, J″, J‴, respectively; or, as it may be expressed, the pairs of points (A, B), (B, C), (C, D), (D, A) belong respectively to the four modes of generation. Now consider the quadrilateral ABCD, and giving it an infinitesimal variation, we have four infinitesimal arcs, AA′, BB′, CC′, DD′, which we shall denote by ds, ds', ds'', ds''', respectively; now let the radii of the four generating circles which touch the quartic at the four pairs of points (A, B), (B, C), (C, D), (D, A) be ρ, ρ', ρ'', ρ''', respectively.

Again let CV, C′,V′, be two consecutive tangents to the focal conic F of the bicircular quartic, and let OAB, OA′B′, be two perpendiculars to CV, C′V′ from the centre of J. Now, if CV, C′V′ intersect the generating circle in RR′, it is evident from geometrical considerations that

$$RR' = \tfrac{1}{2}(BB' - AA'),$$

but $RR' = \rho d\theta$ ($d\theta$ being the angle between two consecutive tangents to F). Hence we have

$$ds' - ds = 2\rho d\theta,$$

and from the three other focal conics and circles of inversion we get three other equations, viz.:—

$$\begin{aligned} ds' - ds'' &= 2\rho'\,d\theta' \\ ds'' - ds''' &= 2\rho''\,d\theta'' \\ ds''' - ds\ \ &= 2\rho'''\,d\theta'''. \end{aligned}$$

Hence we have four equations for determining any of the four quantities ds, ds', ds'', ds''', in terms of the four quantities $\rho d\theta, \rho' d\theta', \rho'' d\theta'', \rho''' d\theta'''$ each of which is separately expressible as the differential of an elliptic integral.

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4. *On the Eighteen Co-ordinates of a Conic in Space. By* WM. SPOTTISWOODE, *F.R.S., &c., &c., President.*

The six co-ordinates of a right line may be derived from the equations of the two planes of which it is the intersection, by eliminating each of the co-ordinates in succession. We may proceed in like manner with the equations of a conic in space. Let the equations be—

$$\begin{gathered} (a, b, c, d, f, g, h, l, m, n)\ (x, y, z, t)^2 = o. \\ \alpha x + \beta y + \gamma z + \delta t = o. \end{gathered}$$

Then eliminating x, y, z, t, in turn, we should obtain four forms which may be written thus:—

$$\begin{aligned} &(CC, BB, FF, BF, CF, BC)\ (y, z, t)^2 = 0, \\ &(AA, CC, GG, CG, AG, CA)\ (z, x, t)^2 = 0, \\ &(BB, AA, HH, AH, BH, AB)\ (x, y, t)^2 = 0, \\ &(FF, GG, HH, GH, HF, FG)\ (x, y, z)^2 = 0. \end{aligned}$$

The 18 quantities AA, BB, ··, the values of which are easily calculated, are "the 18 co-ordinates of a conic in space."

If we represent the three equations—

$$\begin{aligned} AA\alpha + AB\beta + AC\gamma &= 0, \\ BA\alpha + BB\beta + BC\gamma &= 0, \\ CA\alpha + CB\beta + CC\gamma &= 0, \end{aligned}$$

by the formula

$$\begin{matrix}(A, B, C)\\ A, B, C\end{matrix}\ (\alpha, \beta, \gamma) = 0.$$

The 18 co-ordinates will satisfy the 12 equations—

$$\begin{matrix}(A, H, G)\\ A, H, G\end{matrix}\ (\delta, \beta, \gamma) = 0,\quad \begin{matrix}(H, B, F)\\ H, B, F\end{matrix}\ (\alpha, \delta, \gamma) = 0,\quad \begin{matrix}(G, F, C)\\ G, F, C\end{matrix}\ (\alpha, \beta, \delta) = 0.$$

Eliminating $\alpha, \beta, \gamma, \delta$, from these we obtain the following identical relations between the 18 co-ordinates, viz.:—

$$\begin{vmatrix} o, & o, & o, & HH, FH, BH, & GG, FG, CG, & AA, BA, CA \\ HH, GH, AH, & o, & o, & o, & GF, FF, CF, & BA, BB, CB. \\ HG, GG, AG, & HF, FF, BF, & o, & o, & o, & CA, CB, CC. \\ HA, GA, AA, & HB, FB, BB, & GC, FC, CC, & o, & o, & o. \end{vmatrix} = 0.$$

These conditions are nine in number; and, as we are concerned only with the ratios of the co-ordinates, the total number of independent co-ordinates will be $18 - 9 - 1 = 8$, as it should be.

5. *On the Modular Curves.* *By* Professor H. J. S. Smith.

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6. *On the Principal Screws of Inertia of a free or constrained Rigid Body.* *By* Professor R. S. Ball.

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7. *On the Applicability of Lagrange's Equations to certain Problems of Fluid Motion.* *By* Professor J. Purser.

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8. *On the Occurrence of Equal Roots in Lagrange's Determinental Equation of Small Oscillations.* *By* Frederick Purser, *M.A.*

This paper is an endeavour to supply a more elementary proof of the important result which M. Somoff claims to have been the first to establish*—that the existence of equal roots in Lagrange's determinantal equation of small oscillations does not affect the stability of the system. It is further shown that the same conclusion holds for a certain system of differential equations of the first degree having also a physical application.

The solution of the equation of small oscillations—

$$\frac{d^2x_1}{dt^2} = a_{11}x_1 + a_{12}x_2 \quad . \quad . \quad . \quad . \quad . \quad a_{1n}x_n,$$

$$\frac{d^2x_2}{dt^2} = a_{21}x_1 + a_{22}x_2 \quad . \quad . \quad . \quad . \quad . \quad a_{2n}x_n,$$

&c., &c.

(where $a_{12} = a_{21}$, &c.)
as obtained by the method of indeterminate multipliers is—

$$X_1 = x_1\xi_1^{(1)} + x_2\xi_2^{(1)} + \&c. \quad = A_1 \sin(\sqrt{k^{(1)}}\,t + \epsilon^1),$$
$$X_2 = x_1\xi_1^{(2)} + x_2\xi_2^{(2)} + \&c. \quad = A_2 \sin(\sqrt{k^{(2)}}\,t + \epsilon^2),$$

&c., &c.

Where $\xi_1^{(1)}$, $\xi_2^{(1)}$, &c., $\xi_1^{(2)}$ $\xi_2^{(2)}$, &c., are the systems of values of ξ_1, ξ_2, &c., which satisfy the equations,

$$(a_{11} + k)\xi_1 + a_{12}\xi_2 + \&c. = o,$$
$$a_{21}\xi_1 + (a_{22} + k)\xi_2 + \&c. = o,$$

&c., &c.

Corresponding to the roots $k^{(1)}$, $k^{(2)}$, of the determinant in k.

Now, by suitable transformation of this latter system it is shown that when m roots of the determinental equation are equal, the common value being k, the corresponding system of ξs involves $m-1$ arbitrary parameters. Hence in this case, on the one hand, m distinct integrals of the oscillation system are merged in one $X = A \sin(\sqrt{k}\,t + \epsilon)$; on the other, this one, in virtue of the $m-1$ arbitrary parameters implicitly involved in its left-hand member, is equivalent to m distinct integrals.

$$X_1 = A_1 \sin(\sqrt{k}\,t + \epsilon_1) \qquad X_2 = A_2(\sqrt{k}\,t + \epsilon_2),$$

&c.

The occurrence of equal roots in the determinantal equation therefore only diminishes the number of distinct vibration periods, without affecting either the periodic form of solution or the number of distinct integrals.

A second method is employed by the author, based on the theory of orthogonal

* "Sur l'qéuation algébrique à l'aide de laquelle on determine les oscillations très-petites d'un système de points matériels."—'Mémoires de l'Académie de St. Pétersbourg,' vii. série, tome i. No. 14.

transformations, by which it is shown that the m distinct periodic integrals of the symmetric oscillation system, corresponding to m equal roots of the equation for k, can be made to appear by a series of successive reduction, while the same reduction applied to an unsymmetric system leads necessarily to terms in which t occurs outside the sine or cosine.

Lastly, the same general conclusions are established for the linear equations.

$$\frac{dx_1}{dt} = a_{11}x_1 + a_{12}x_2 + \quad \cdot \cdot \cdot \quad a_{1n}x_n,$$

$$\frac{dx_2}{dt} = a_{21}x_1 + a_{22}x_2 + \quad \cdot \cdot \cdot \cdot \quad a_{2n}x_n,$$

&c., &c.

where $$a_{11} = a_{22} = \&c. = o \qquad a_{12} + a_{21} = o, \&c.$$

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9. *On Halphen's New Form of Chasles's Theorem on Systems of Conics satisfying Four Conditions.* By Dr. T. ARCHER HIRST, *F.R.S.*

The theorem in question is expressed by the formula

$$n = a\mu + \beta\nu,$$

where μ and ν are the characteristics of the system of conics satisfying four of the five conditions, and a and β are numbers which depend solely upon the fifth condition. Amongst the n conics given by the formula degenerate ones are, of course, included, provided they satisfy the five conditions.

From Halphen's new form of the theorem, however, these degenerate conics are excluded, and the result is the number of proper conics which satisfy the five conditions in question. Halphen's paper will be published shortly in the 'Proceedings of the London Mathematical Society.'

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10. *On the Law of Force to any Point when the Orbit is a Conic.* By J. W. L. GLAISHER, *M.A.*, *F.R.S.*

1. Sir W. R. Hamilton, in the 'Proceedings' of the Royal Irish Academy for 1846 (vol. iii., p. 308), proved that if a body be attracted to a fixed point, with a force varying directly as the distance from that point, and inversely as the cube of the distance from a fixed plane, the body will describe a conic, of which the plane intersects the fixed plane in a straight line, which is the polar of the fixed point with respect to the conic. The author showed that if the distance of any point from the fixed point O be denoted by r, and if the perpendicular from any point P upon the fixed plane be denoted by p, so the law of force to O is, according to Sir W. R. Hamilton's law, $\frac{\mu r}{p^3}$, then the periodic time is $\frac{2\pi}{\sqrt{\mu}} p_o{}^3$, where p_o denotes the perpendicular from the centre of the orbit upon the fixed plane. For example, if the plane of motion is parallel to the fixed plane, p is constant, $= p_o$, so that the force to $O = \frac{\mu}{p_o{}^3} r = \mu' r$, say, and the periodic line $= \frac{2\pi}{\sqrt{\mu}} p_o{}^3 = \frac{2\pi}{\sqrt{\mu'}}$. It follows also that all the orbits having their centres in the same plane parallel to the fixed plane are described in the same periodic time.

2. Considering only the case of motion in the plane of xy, and combining the above theorem with formulæ given by MM. Darboux and Halphen ('Comptes Rendus', t. 84, pp. 760–762, 936–941), it follows that if the orbit

$$(ax + by + c)^2 = Ax^2 + 2Hxy + By^2$$

be described about the origin under the action either of the force

$$\frac{\mu r}{(ax+by+c)^3}$$

or the force

$$\frac{\mu r}{(Ax^2+2Hxy+By^2)^{\frac{3}{2}}},$$

the periodic time will be

$$\frac{2\pi}{\sqrt{\mu}}\left\{\frac{c(AB-H^2)}{AB-H^2-(Ab^2+Ba^2-2Hab)}\right\}^{\frac{3}{2}}.$$

3. In the case of an elliptic orbit described about any point O, the law of force to O may be put in the form

$$\frac{\mu}{r^2(b^2-p_1p_2)^{\frac{3}{2}}},$$

where b is the semi-axis minor; r is the distance OP of the body P from O; p_1, p_2 are the perpendiculars from the foci S, H upon POP′ (the chord through P and O), and p_1, p_2 have the same or opposite signs according as S, H are on the same or opposite sides of PP′. The periodic time is then

$$\frac{2\pi}{\sqrt{\mu}}(ab)^{\frac{3}{2}},$$

a being the semi-axis major.

4. If a parabola be described about any point O, the force tending to O, at any point P in the orbit, is equal to $\mu\,\frac{\text{OP}}{\text{OM}^3}$ where OM is drawn parallel to the axis meeting the tangent at P in M.

This, and the expression for the force in § 3, may be deduced from the scholium to Prop. xvii. of Newton's 'Principia.'

The Paper of which the above is an abstract will appear in the 'Monthly Notices' of the Royal Astronomical Society.

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11. *Note on the Geometrical Treatment of Bicircular Quartics.* *By* Frederick Purser, *M.A.*

The author pointed out that some of the leading properties of these curves might be readily deduced geometrically from the definition of the curve as a locus. This definition may be thus stated: "The bicircular quartic is the locus of points P, whose *quasi polars* to a circle J touch a conic F"; by *quasi polar* being understood the parallel to the polar half way between point and polar.

Introducing the circular points ω, ω', the bicircular becomes the binodal quartic, and the *quasi polar* the companion chord of intersection of the lines $P\omega$, $P\omega'$ with the conic J.

In particular, this method yields a geometrical proof of the theorem of orthogonal section of two confocal quartics, and the same mode of proof is applicable to the corresponding theorem for cyclides.

Poncelet's porism on the inscription of polygons whose sides pass alternately through the two nodes of a binodal quartic is shown to be reducible to the porism of the in-and-circumscribed polygon for conics. Lastly, it is shown that this mode of treatment leads to the following theorem, which is, so far as the author is aware, new:—"If a conic U touch a line L, a conic V, and have double contact with a third conic W, the chord of contact envelopes a binodal quartic, of which the intersections of L and W are the nodes."

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12. *On Quadric Transformation.* *By* Professor H. J. S. Smith.

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13. *On Certain Linear Differential Equations. By the* Rev. ROBERT HARLEY, *F.R.S.*

By an ingenious application of Murphy's theorem, Mr. Rawson has shown that if $u_n = \frac{1}{n}\Sigma y^n$, the summation extending to any number of the roots of the algebraical equation

$$y^m + ay^r + bx = o \ldots (a),$$

y being considered as a function of x, then

$$\frac{du_{n+r}}{dx} = -\frac{bm}{a(m-r)}\left(x\frac{du_n}{dx} - \frac{n}{m}u_n\right) \ldots (\beta),$$

$$\frac{du_{n+m}}{dx} = \frac{br}{m-r}\left(x\frac{du_n}{dx} - \frac{n}{r}u_n\right) \ldots (\gamma).$$

Mr. Rawson has also shown how the "differential resolvent" of (a) may be calculated by means of the equations (β) and (γ), when particular values are assigned to m and r. The object of this paper is to show, first, that Mr. Rawson's differential equations may be readily derived from the algebraical equation, without the aid of Murphy's theorem, by a process suggested by Professor Cayley; and, secondly, that Mr. Rawson's results may be generalised and presented in a compact symbolical form.

It will be convenient to deal with the equation

$$ay^m + by^r + cx = o. \tag{1}$$

which is unaltered when a, m are interchanged with b, r. Differentiate (1) with respect to x, and multiply the result into y^n, then

$$(amy^{m+n-1} + bry^{r+n-1})\, y' + cy^n = o,$$

where differentiation is denoted by an accent; but

$$my^{n-1}(ay^m + by^r + cx)\, y' = o;$$

whence, eliminating y^{m+n-1}, we have

$$b\,(m-r)\, y^{r+n-1}y' + cmxy^{n-1}y' - cy^n = o,$$

which, summing for any number if the roots of y, gives

$$u'_{r+n} = -\frac{c}{b}\left(\frac{m}{m-r}u'_n - \frac{n}{m-r}u_n\right). \tag{2}$$

Interchange a, m with b, r; then

$$u'_{m+n} = -\frac{c}{a}\left(\frac{r}{r-m}u'_n - \frac{n}{r-m}u_n\right). \tag{3}$$

These results, viz. (2) and (3), agree with Mr. Rawson's equations (β) and (γ)

They may be otherwise written

$$\mathrm{D}u_{r+n} = -\frac{c}{b}\,x\left(\frac{m}{m-r}\mathrm{D} - \frac{n}{m-r}\right)u_n. \tag{4}$$

$$\mathrm{D}u_{n+m} = -\frac{c}{a}\,x\left(\frac{r}{r-m}\mathrm{D} - \frac{n}{r-m}\right)u_n \tag{5}$$

where $\mathrm{D} = x\frac{d}{dx}$.

Adopting the usual factorial notation, viz.:—

$$[\theta]^{\alpha} = \theta\,(\theta-1)\,(\theta-2)\ldots(\theta-\alpha+1),$$

according to which

$$[\theta]^{\alpha+\beta} = [\theta]^{\alpha}[\theta-\alpha]^{\beta},$$

and effecting reductions by the aid of the theorem

$$f(\mathrm{D})x^a u = x^a f(\mathrm{D}+a)u,$$

or $$x^a f(D)u = f(D-a)x^a u,$$
we may generalise thus:—

Operate with $[D-1]^{t-1}$ on both members of (4), then

$$[D]^t u_{r+n} = -\frac{c}{b} x \left(\frac{m}{m-r} D - \frac{n}{m-r}\right) [D]^{t-1} u_n$$

Write $r+n$ for n, then

$$[D]^t u_{2r+n} = \left(-\frac{c}{b}\right)^2 x^2 \left[\frac{m}{m-r} D - \frac{n}{m-r} + 1\right]^2 [D]^{t-2} u_n.$$

So generally,

$$[D]^t u_{qr+n} = \left(-\frac{c}{b}\right)^q x^q \left[\frac{m}{m-r} D \quad \frac{n}{m-r} + q - 1\right]^q [D]^{t-q} u_n$$

By applying the same process to (5), or more simply by writing, in (6), p for q and interchanging a, m with b, r, we find

$$[D]^t u_{pm+n} = \left(-\frac{c}{a}\right)^p x^p \left[\frac{r}{r-m} D - \frac{n}{r-m} + p - 1\right]^p [D]^{t-p} u_n$$

$$= \left(\frac{c}{a}\right)^p x^p \left[\frac{r}{m-r} D - \frac{n}{m-r}\right]^p [D]^{t-p} u_n.$$

Therefore, when $qr = pm$,

$$\left[\frac{r}{m-r} D - \frac{n}{m-r}\right]^p [D]^{t-p} u_n$$

$$= (-)^q \frac{a^p c^q}{b^q c^p} x^{q-p} \left[\frac{m}{m-r} D - \frac{n}{m-r} + q - 1\right]^q [D]^{t-q} u_n. \quad (6)$$

If we make $t = p$, and interpret $[D]^0$ by 1, this equation becomes

$$\left[\frac{r}{m-r} D - \frac{n}{m-r}\right]^p u_n$$

$$= (-)^q \frac{a^p c^q}{b^q c^p} x^{q-p} \left[\frac{m}{m-r} D - \frac{n}{m-r} + q - 1\right]^q [D]^{p-q} u_n, \quad (7)$$

which may be transformed into

$$\left[\frac{r}{m-r} D - \frac{n}{m-r}\right]^p [D]^{q-p} u_n = (-)^q \frac{a^p c^q}{b^q c^p} x^{q-p} \left[\frac{m}{m-r} D - \frac{n}{m-r} + q - 1\right]^q u_n, \quad (8)$$

an equation which may be obtained directly from (6) by making $t = q$.

When m and r are prime to each other, the lowest values of p and q are r and m respectively, and either (7) or (8) may be written in the form

$$\left[\frac{r}{m-r} x \frac{d}{dx} - \frac{n}{m-r}\right]^r \left[x \frac{d}{dx}\right]^{m-r} u$$

$$= (-)^m \frac{a^r c^m}{b^m c^r} \left[\frac{m}{m-r} x \frac{d}{dx} - \frac{n}{m-r} - 1\right]^m x^{m-r} u_n, \quad (9)$$

or in the form

$$\left[\frac{r}{r-m} x \frac{d}{dx} - \frac{n}{r-m}\right]^m \left[x \frac{d}{dx}\right]^{r-m} u_n$$

$$= (-)^r \frac{b^m c^r}{a^r c^m} \left[\frac{r}{-m} x\, d - \frac{n}{r-m} - 1\right]^r x^{r-m} u^n. \quad (10)$$

The general integral is

$$u_n = c_1 y_1^n + c_2 y_2^n \cdots + c_r y_r^n \cdots + c_m y_m^n,$$

the final term being $c_m y^{\,n}$ or $c_r y^{\,n}$, according as m or r is the greater. In the former case (9), and in the latter (10), is the more convenient form.

The substitution $\begin{pmatrix} r, & m, & b \\ -r, & m-r, & c \end{pmatrix}$ changes the algebraical equation (1) into

$$ay^m + bxy^r + c = o, \tag{11}$$

and the same substitution changes the differential equation (9) into

$$\left[-\frac{r}{m}x\frac{d}{dx}-\frac{n}{m}\right]^{-r}\left[x\frac{d}{dx}\right]^{m}u_n = (-)^{m-r}\frac{b^m c^r}{a^r c^m}\left[\frac{m-r}{m}x\frac{d}{dx}-\frac{n}{m}-1\right]^{m-r} x\ u_n,$$

which, since

$$\left[-\theta\right]^{-a} = \frac{1}{[-\theta+a]^a} = \frac{(-1)^a}{[\theta-1]^a},$$

may be written

$$\left[x\frac{d}{dx}\right]^{m}u_n = (-)^{m}\frac{b^m c^r}{a^r c^m}\left[\frac{r}{m}x\frac{d}{dx}+\frac{n}{m}-1\right]^{r}\left[\frac{m-r}{m}x\frac{d}{dx}-\frac{n}{m}-1\right]^{m-r} x^m u_n. \tag{12}$$

This confirms a result obtained by the author some years ago by the aid of Lagrange's theorem, viz., that the differential equation

$$a^r\left[x\frac{d}{dx}\right]^{n}u = \left[\frac{n-r}{n}x\frac{d}{dx}+\frac{m}{n}-1\right]^{n-r}\left[\frac{r}{n}x\frac{d}{dx}-\frac{m}{n}-1\right]^{r}x^{n-r}u$$

is satisfied by the m^{th} power of any root of the equation.

$$y^n - xy^{n-r} + a = o.$$

See Boole's 'Differential Equations,' Supplementary Volume, page 190, where the reader should correct a misprint in the seventh line from the top of the page; the factor x^n should be x^{n-r}.

When m and r are not prime to each other, a reduction in the order of the differential equation may be effected. For, if $m = a\mu$, and $r = a\rho$, a being the greatest common measure of m and r, the condition $pm = qr$ is satisfied by making $p = \rho$ and $q = \mu$, and we have, corresponding to the equations (9), (10), and (12) the three following, viz:—

$$\left[\frac{\rho}{\mu-\rho}x\frac{d}{dx}-\frac{n}{a(\mu-\rho)}\right]^{\rho}\left[x\frac{d}{dx}\right]^{\mu-\rho}u_n$$

$$= (-)^{\mu}\frac{a^\rho c^\mu}{b^\mu c^\rho}\left[\frac{\mu}{\mu-\rho}x\frac{d}{dx}-\frac{n}{a(\mu-\rho)}-1\right]^{\mu}x^{\mu-\rho}u_n. \tag{13}$$

$$\left[\frac{\mu}{\rho-\mu}x\frac{d}{dx}-\frac{n}{a(\rho-\mu)}\right]^{\mu}\left[x\frac{d}{dx}\right]^{\rho-\mu}u_n$$

$$= (-)^{\rho}\frac{b^\mu c^\rho}{a^\rho c^\mu}\left[\frac{\rho}{\rho-\mu}x\frac{d}{dx}-\frac{n}{a(\rho-\mu)}-1\right]^{\rho}x^{\rho-\mu}u_n, \tag{14}$$

either of which is satisfied by the n^{th} power of any root of the algebraic equation (1). And

$$\left[x\frac{d}{dx}\right]^{\mu}u_n = (-)^{\mu}\frac{b^\mu c^\rho}{a^\rho c^\mu}\left[\frac{\rho}{\mu}x\frac{d}{dx}+\frac{n}{a\mu}-1\right]^{\rho}\left[\frac{\mu-\rho}{\mu}x\frac{d}{dx}-\frac{n}{a\mu}-1\right]^{\mu-\rho}x^{\mu}u_n, \tag{15}$$

which is satisfied by the n^{th} power of any root of the algebraic equation (11).

The "differential resolvents" of (1) and (11) are formed by making $n = 1$, in which case each of the differential equations reduces to an order lower by unity than itself, in accordance with the theory of differential resolvents. The author noticed other cases in which, for particular values of n, the differential equations admit of reduction.

The passage from the symbolical to the ordinary form of linear differential equations was shown to involve no practical difficulty.

14. *On the Solution of a Differential Equation allied to Riccati's.* *By* J. W. L. Glaisher, *M.A., F.R.S.*

The equation referred to was the well-known differential equation

$$\frac{d^2u}{dx^2}-a^2u=\frac{i(i+1)}{x^2}u \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

which is transformable into Riccati's equation

$$\frac{d^2w}{dz^2}-a^2z^{2q-2}w=o$$

by the substitutions

$$u=x^{-i}w, \qquad x=\frac{1}{q}z^q,$$

where $q=\dfrac{1}{2i+1}$.

The author stated that he had found that the differential equation (1) was satisfied by the coefficient of h^{i+1} in the expansion in ascending powers of x of the expression

$$e^{a\sqrt{(x^2+xh)}},$$

so that the complete integral of (1) was

$$u=\text{A . coefficient of } h^{i+1} \text{ in } e^{a\sqrt{(x^2+xh)}}$$
$$+\text{B . coefficient of } h^{i+1} \text{ in } e^{-a\sqrt{(x^2+xh)}}.$$

To prove this, consider the partial differential equation

$$\frac{d^2v}{dx^2}-a^2v=\frac{h^2}{x^2}\frac{d^2v}{dh^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

A particular integral of this is

$$v=e^{a\sqrt{(x^2+xh)}},$$

for from this value of v we obtain at once by differentiation

$$\frac{d^2v}{dx^2}=a^2v\,\frac{(x+\frac{1}{2}h)^2}{x^2+xh}-av\,\frac{\frac{1}{4}h^2}{(x^2+xh)^{\frac{3}{2}}}$$

$$\frac{d^2v}{dh^2}=a^2v\,\frac{\frac{1}{4}x^2}{x^2+xh}-av\frac{\frac{1}{4}x^2}{(x^2+xh)^{\frac{3}{2}}},$$

whence we see that (2) is satisfied.

Let the above value of v be expanded in ascending powers of h, so that

$$e^{a\sqrt{(x^2+xh)}}=\text{P}_0+\text{P}_1h\ldots+\text{P}_ih^i+\text{P}_{i+1}h^{i+1}+\ \&\text{c.},$$

then

$$\frac{d^2v}{dx^2}-a^2v=\ .\ .\ .\ .+\left(\frac{d^2\text{P}_{i+1}}{dx^2}-a^2\text{P}_{i+1}\right)h^{i+1}+\ \&\text{c.},$$

$$\frac{h^2}{x^2}\frac{d^2v}{dh^2}\quad=\ .\ .\ .\ .+\frac{(i+1)i}{x^2}\text{P}_{i+1}h^{i+1}+\ \&\text{c.},$$

and therefore, P_{i+1} satisfies the differential equation

$$\frac{d^2u}{dx^2}-a^2u=\frac{i(i+1)}{x^2}u.$$

In this solution it has been assumed that $i=$ a positive integer; but if i be negative $=-i'-1$, we have $i(i+1)=(i'+1)i'$, so that we may replace i by i', which is positive; and thus the solution applies when $i=\pm$ an integer, corresponding to the integrable cases of Riccati's equation, viz., when $q=\pm$ the reciprocal of an uneven integer. By considering the coefficient of h^{i+1} in the direct expansion of $e^{a\sqrt{(x^2+xh)}}$

$$=1+a(x^2+xh)^{\frac{1}{2}}+\frac{a^2}{1\,.\,2}(x^2+xh)+\ \&\text{c.},$$

in
$$e^{ax} \cdot e^{a(\sqrt{(x^2+xh)}-x)}$$
$$= e^{ax}\left[1 + a\left\{\sqrt{(x^2+xh)} - x\right\} + \frac{a^2}{1.2}\left\{\sqrt{(x^2+xh)} - x\right\}^2 + \text{\&c.},\right.$$
and in
$$e^{-ax} \cdot e^{a(\sqrt{(x^2+xh)}+x)}$$
$$= e^{-ax}\left[1 + a\left\{\sqrt{(x^2+xh)} + x\right\} + \frac{a^2}{1.2}\left\{\sqrt{(x^2+xh)} + x\right\}^2 + \text{\&c.},\right.$$
we obtain by means of the expansions
$$\left\{\sqrt{(x^2+xh)} - x\right\}^n = \frac{1}{2^n}h^n\left\{1 - n\frac{h}{4x} + \frac{n(n+3)}{1.2}\frac{h^2}{4^2x^2} - \frac{n(n+4)\ (n+5)}{1.2.3}\frac{h^3}{4^3x^3} + \text{\&c.}\right\}$$
$$\left\{\sqrt{(x^2+xh)} + x\right\}^n = 2^n x^n\left\{1 + n\frac{h}{4x} + \frac{n(n-3)}{1.2}\frac{h^2}{4^2x^2} + \frac{n(n-4)\ (n-5)}{1.2.3}\frac{h^3}{4^3x^3} + \text{\&c.}\right\}$$
the general integrals of the differential equation in the different forms of which it is known to be susceptible.

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15. *On Certain Special Enumerations of Primes.* By J. W. L. Glaisher, *M.A., F.R.S.*

The paper related to (1) prime-pairs, and (2) primes of the form $4n+1$ and the form $4n+3$ enumerated separately.

I. *Prime-pairs.*—By a prime-pair is meant a pair of primes separated by only one number; thus, 11 and 13, 17 and 19, 29 and 31, &c., are prime-pairs. It is clear that as the number of primes decreases as we ascend higher in the series of numerals, the number of prime-pairs must decrease also, and the object of the enumeration was to examine the rapidity of this decrease. The enumerations relate to the first hundred chiliads (100,000 numbers) of each of the six millions over which Burckhardt's and Dase's tables extend; and the number of prime-pairs in each ten chiliads is shown in the following table:—

	First Million	Second Million	Third Million	Seventh Million	Eighth Million	Ninth Million
I	206	84	67	61	50	67
II	137	69	65	62	53	45
III	125	73	75	51	53	47
IV	124	69	63	45	57	43
V	114	79	55	56	63	58
VI	106	62	67	57	46	54
VII	94	69	66	45	41	55
VIII	102	71	64	55	54	61
IX	109	65	69	60*	51	45
X	108	84	53	47	57	43
Total for the hundred chiliads	1225	725	644	545	525	518

* The prime-pair $\left\{\begin{matrix}6,089,999\\6,090,001\end{matrix}\right\}$ is counted as belonging to the group 6,080,000—6,090,000 only.

The explanation of the table is that the number of prime-pairs between 0 and 10,000 is 206; between 10,000 and 20,000 is 137; . . . between 90,000 and 100,000 is 108; between 1,000,000 and 1,010,000 is 84; between 1,010,000 and 1,020,000

is 69, &c. Thus, for example, the number of prime-pairs between 7,070,000 and 7,080,000 is 54; and between 8,090,000 and 8,100,000 is 43.

The total number of prime-pairs between 0 and 100,000 is 1225; between 1,000,000 and 1,100,000 is 725; . . . and between 8,000,000 and 8,100,000 is 518, as shown in the last line of the table; and it is interesting to compare these with the numbers of primes between the same limits which are respectively 9,593, 7,216, 6,874, 6,397, 6,369, 6,250. The numbers of prime-pairs are thus rather less than one-tenth of the numbers of primes in the same intervals. It should be stated that among the prime-pairs 1 and 3, 3 and 5, 5 and 7 are counted (2 being ignored), and that among the primes 1 and 2 are both counted. In the 600 chiliads, the greatest number of prime-pairs contained in any one chiliad is 36 in the first chiliad; while one chiliad (8,014,000—8,015,000) contained no prime-pair. For a more complete account of the enumeration see 'Messenger of Mathematics,' vol. viii. pp. 28–33 (June, 1878).

II. *Primes of the form* $4n+1$ *and* $4n+3$.—This enumeration only extends at present over the first hundred chiliads of each of the first three millions. The results are shown in the following table:—

	First Million			Second Million			Third Million		
	Number of $4n+1$ Primes	Number of $4n+3$ Primes	Total number of Primes	Number of $4n+1$ Primes	Number of $4n+3$ Primes	Total number of Primes	Number of $4n+1$ Primes	Number of $4n+3$ Primes	Total number of Primes
I	610	619	1,229	391	362	753	351	354	705
II	516	517	1,033	367	352	719	345	346	691
III	486	497	983	369	363	732	349	344	693
IV	474	484	958	347	354	701	340	350	690
V	464	466	930	361	370	731	343	328	671
VI	469	455	924	349	349	698	356	340	696
VII	431	447	878	362	354	716	355	339	694
VIII	454	448	902	372	350	722	343	331	674
IX	445	431	876	352	354	706	339	347	686
X	435	444	879	373	365	738	341	333	674
Total for the hundred chiliads	4,784	4,808	9,592	3,613	3,573	7,216	3,462	3,412	6,874

The explanation is the same as in the case of the previous table—viz., the numbers of primes of the forms $4n+1$ and $4n+3$ between 0 and 10,000 are 610 and 619 respectively; between 10,000 and 20,000 are 516 and 517 respectively; between 1,000,000 and 1,010,000 are 391 and 362 respectively, and so on. The enumeration (which was undertaken at the suggestion of Professor Tchébychef) is scarcely extensive enough to afford valuable results; but, owing to the great difference in the properties of the primes of the two forms, the comparison between their frequency of occurrence possesses considerable interest. The numbers given in the table are the result of a duplicate enumeration; but a third enumeration will be required, in order to render it certain that they are absolutely free from error.

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16. *Notes on Circulating Decimals. By* J. W. L. GLAISHER, *M.A., F.R.S.*

The author alluded to the advantage, in considering the complete theory of the periods of circulating decimals, of including all the periods corresponding to a given

divisor q. Thus, for example, suppose $q=39$: there are four periods, viz. dividing 1, 38, 2, and 37 by 39, we have

39)	1	$(\cdot\dot{0}$	39)	38	$(\cdot\dot{9}$	39)	2	$(\cdot\dot{0}$	39)	37	$(\cdot\dot{9}$
	10	2		29	7		20	5		19	4
	22	5		17	4		5	1		34	8
	25	6		14	3		11	2		28	7
	16	4		23	5		32	8		7	1
	4	$\dot{1}$		35	$\dot{8}$		8	$\dot{2}$		31	$\dot{7}$

the remainders being written in the column in the middle and the corresponding quotient digits at the side, *e.g.* 10 divided by 39 gives quotient 0 and remainder 10, 100 divided by 39 gives quotient 2 and remainder 22, 220 divided by 39 gives quotient 5 and remainder 25, and so on. It follows that

$$\frac{1}{39} = \dot{0}2564\dot{1}, \qquad \frac{10}{39} = \cdot\dot{2}5641\dot{0}, \qquad \frac{22}{39} = \dot{5}6410\dot{2}$$
$$\frac{25}{39} = \cdot\dot{6}4102\dot{5}, \qquad \frac{16}{39} = \cdot\dot{4}1025\dot{6}, \qquad \frac{4}{39} = \cdot\dot{1}0256\dot{4}$$

and the numbers 1, 10, 22, 25, 16, 4 are such that if we divide any one of them by 39, we obtain the others in this order, and all the fractions $\frac{1}{39}, \frac{10}{39}, \ldots \frac{4}{39}$ give rise to the same period, though the commencement is made in each case at a different place.

Considering periods in which the digits and their cyclical order are the same (though the commencement may be made at a different place) as the same period, we see that 39 has four periods, each containing 6 digits. In general, the number q (supposed prime to 10) will have f periods each containing a figures, a and f being connected by the equation $af=\phi(q)$, where $\phi(q)$ denotes the number of numbers less than q and prime to it. Calling the period to which $\frac{1}{q}$ belongs, the leading period, if the remainder $q-1$ belongs to the leading period, the two halves of each period will be complementary, while if it does not, the periods will form pairs, the periods in each pair being complementary to one another. The theory is rendered much more simple if all the periods be considered, than if attention be confined to the leading period.

The author had formed a table showing the values of a and f for each number prime to 10 up to 1000: this table was obtained by counting the number of periods and the number of digits in each period in Henry Goodwyn's 'Table of Circles' (1823), which gives all the periods of the numbers prime to 10 up to 1024. The table was verified by multiplying the values of a and f, which, in every case was found to be equal to $\phi(q)$. Other such tables that have been given have usually related only to primes, and to the number of digits in the period. There is a table of periods in vol. ii. of Gauss's 'Werke,' pp. 412-434, but it is less complete than Goodwyn's. With regard to the number of figures in the periods of numbers, it is known that if the periods of the primes N, P, Q ... contain respectively n, p, q ... digits, then NPQ ... has a period of a figures, a being the least common multiple of n, p, q .... The demonstration does not apply to the case of the power of a prime. Generally, it is found that N^2 has a period of nN digits, N^3 of nN^2 digits, &c., but for an obvious reason this is not true when $N=3$, and also it is not true when $N=487$; for 487 has a period of 486 digits and 487^2 has also a period of 486 digits. It is, however, true for all other primes less than 1000, so that if N, P, Q ... be any primes, each less than 1000 (3 and 487 excepted), the period of $N^\alpha P^\beta Q^\gamma$... contains a digits, a being the least common multiple of $nN^{\alpha-1}$, $pP^{\beta-1}$, $qQ^{\gamma-1}$, ... The discovery that 487 divides its own periods is due to Desmarest ('Théorie des Nombres,' 1852, p. 295), who seems to have determined by actual division that no other prime up to 1000 possessed the same property. In the event of a prime p being a factor of its period, we have $10^{p-1}\equiv 1 \pmod{p^2}$. By Fermat's theorem, we know that $10^{p-1}\equiv 1 \pmod{p}$, but the theorem throws no light upon whether $10^{p-1}\equiv 1 \pmod{p^2}$. The question was proposed by Abel in t. iii. p. 212 of Crelle's 'Journal:' "Can $x^{p-1}-1$, where p is a prime and x an integer

less than p, be a multiple of p^2?" This was answered in the affirmative by Jacobi on p. 301 of the same volume, who showed that $3^{10} \equiv 1$ (mod. 11^2), $14^{28} \equiv 1$ (mod. 29^2), and $18^{36} \equiv 1$ (mod. 37^2). (See also Jacobi's 'Canon Arithmeticus' (1839), p. xxxiv). Desmarest, in fact, obtained a solution of the congruence $x^{p-1} \equiv 1$ (mod. p^2) for $x=10$, viz. $10^{486} \equiv 1$ (mod. 487^2). The fact that only one value of p should occur up to 1000 for which the congruence is satisfied is not remarkable when the diminution of the probability of a number being a factor of its period, as we ascend in the series of primes, is considered. Regarding the period merely as a number taken at random, we can see how small is the chance that a large prime should leave a zero remainder when divided into its period; but there is no reason to suppose that there are not values of p for which $10^{p-1} \equiv 1$ (mod. p^3), &c.

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17. *Elementary Demonstration of the Theorem of Multiplication of Determinants. By* M. Falk, *Docens of Mathematics in the University of Upsala.*

The present article is intended to give a rigorous demonstration of the important theorem above mentioned, founded upon the same elementary principles (elimination between two systems of equations) as the demonstration which is given by Brioschi in his excellent Treatise on Determinants, and is reproduced by Schellbach in his German translation of this work. To the demonstration of Brioschi, I think one must object that it is incomplete, as taking no account of the numerators of the two quotients, from the equality of which that of the denominators is concluded.

In the following we use the notations:—

$$(1) \quad \ldots\ldots \quad \begin{cases} (uv) = u_1v_1 + u_2v_2 + \quad \ldots \quad + u_nv_n, \\ (uv)_1 = u_2v_2 + u_3v_3 + \quad \ldots \quad + u_nv_n, \end{cases}$$

whence

$$(2) \quad \ldots\ldots \quad (uv)_1 = (uv) - u_1v_1,$$

and

$$(3) \quad \ldots\ldots \quad \begin{cases} A = \begin{vmatrix} (a\alpha), & (a\beta), & (a\gamma), \ldots (a\kappa) \\ (b\alpha), & (b\beta), & (b\gamma), \ldots (b\kappa) \\ (c\alpha), & (c\beta), & (c\gamma), \ldots (c\kappa) \\ \cdot & \cdot & \cdot & \cdot \\ (k\alpha), & (k\beta), & (k\gamma), \ldots (k\kappa) \end{vmatrix} \\ D = \begin{vmatrix} a_1, & a_2, & a_3, \ldots a_n \\ b_1, & b_2, & b_3, \ldots b_n \\ c_1, & c_2, & c_3, \ldots c_n \\ \cdot & \cdot & \cdot & \cdot \\ k_1, & k_2, & k_3, \ldots k_n \end{vmatrix} \quad \Delta = \begin{vmatrix} \alpha_1, & \alpha_2, & \alpha_3 \ldots \alpha_n \\ \beta_1, & \beta_2, & \beta_3 \ldots \beta_n \\ \gamma_1, & \gamma_2, & \gamma_3 \ldots \gamma_n \\ \cdot & \cdot & \cdot & \cdot \\ \kappa_1, & \kappa_2, & \kappa_3 \ldots \kappa_n \end{vmatrix} \end{cases}$$

$$(4) \quad \ldots\ldots \quad \begin{cases} A_1 = \begin{vmatrix} (b\beta)_1, & (b\gamma)_1 \ldots (b\kappa)_1 \\ (c\beta)_1, & (c\gamma)_1 \ldots (c\kappa)_1 \\ \cdot & \cdot & \cdot \\ (k\beta)_1, & (k\gamma)_1 \ldots (k\kappa)_1 \end{vmatrix} \\ D_1 = \begin{vmatrix} b_2, & b_3 \ldots b_n \\ c_2, & c_3 \ldots c_n \\ \cdot & \cdot & \cdot \\ k_2, & k_3 \ldots k_n \end{vmatrix} \quad \Delta_1 = \begin{vmatrix} \beta_2, & \beta_3 \ldots \beta_n \\ \gamma_2, & \gamma_3 \ldots \gamma_n \\ \cdot & \cdot & \cdot \\ \kappa_2, & \kappa_3 \ldots \kappa_n \end{vmatrix} \end{cases}$$

Now comparing the systems (3) and (4), we see that the constituents of A in (3) are composed of those of D and Δ, exactly in the same manner as the constituents in A_1 of those in D_1 and Δ_1. The determinants in (3) are of the n^{th}, those in (4) of the $(n-1)^{\text{st}}$ order. The theorem, therefore, will be generally demonstrated, if we prove:

1) That it holds for determinants of the second order, and,

2) That, if it holds for determinants of the $(n-1)^{\text{st}}$, it must also be true for those of the n^{th} order; *i.e.* that if $A_1 = D_1\Delta_1$, then $A = D\Delta$.

1) Developing the determinant of the left member, the following identity becomes immediately proved:—

$$\begin{vmatrix} x_1\xi_1 + x_2\xi_2, & x_1\eta_1 + x_2\eta_2 \\ y_1\xi_1 + y_2\xi_2, & y_1\eta^1 + y_2\eta_2 \end{vmatrix} = \begin{vmatrix} x_1, & x_2 \\ y_1, & y_2 \end{vmatrix} \cdot \begin{vmatrix} \xi_1, & \xi_2 \\ \eta_1, & \eta_2 \end{vmatrix}$$

Thus the theorem holds for determinants of the second order.

2) Suppose the theorem hold for determinants of the $(n-1)^{st}$ order, *i.e.*, suppose that

(5) . . . . $A_1 = D_1 . \Delta_1$;

then it shall be proved that

$$A - D\Delta.$$

Now, Δ_1 being a certain minor of Δ, we denote by $\Delta_1, \Delta_2, \ldots, \Delta_n$ the minors of Δ which correspond to the constituents of its first column. Then, by a known property of determinants, we have the identities:

$$\begin{aligned} a_1\Delta_1 + \beta_1\Delta_1 + \gamma_1\Delta_3 + \ldots, +, \kappa_1\Delta_n &= \Delta, \\ a_2\Delta_1 + \beta_2\Delta_2 + \gamma_2\Delta_3 + ,\ldots, + \kappa_2\Delta_n &- o, \\ a_3\Delta_1 + \beta_3\Delta_2 + \gamma_3\Delta_3 + ,\ldots, + \kappa_3\Delta_n &= o, \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad & \cdot \quad \cdot \quad \cdot \\ a_n\Delta_1 + \beta_n\Delta_2 + \gamma_n\Delta_3, + ,\ldots + \kappa_n\Delta_n &= o. \end{aligned}$$

Multiplying these equations by $a_1, a_2, a_3, \ldots, a_n$ respectively, and adding them, we obtain the first of the next following equations. In the same manner, the others are obtained by using as successive multipliers the constituents of every one of the other rows in D. By the notations (1) we thus get:

$$\begin{aligned} (a\alpha)\Delta_1 + (a\beta)\Delta_2 + (a\gamma)\Delta_3 + ,\ldots, + (a\kappa)\Delta_n &= a_1\Delta, \\ (b\alpha)\Delta_1 + (b\beta)\Delta_2 + (b\gamma)\Delta_3 + ,\ldots, + (b\kappa)\Delta_n &= b_1\Delta, \\ (c\alpha)\Delta_1 + (c\beta)\Delta_2 + (c\gamma)\Delta_3 + ,\ldots, + (c\kappa)\Delta_n &= c_1\Delta, \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad & \cdot \quad \cdot \quad \cdot \\ (k\alpha)\Delta_1 + (k\beta)\Delta_2 + (k\gamma)\Delta_3 + ,\ldots, + (k\kappa)\Delta_n &= k_1\Delta. \end{aligned}$$

Now eliminating $\Delta_2, \Delta_3, \ldots, \Delta_n$ between these equations, and putting

$$\nabla = \begin{vmatrix} a_1, & (a\beta), & (a\gamma), & \ldots, & (a\kappa) \\ b_1, & (b\beta), & (b\gamma), & \ldots, & (b\kappa) \\ c_1, & (c\beta), & (c\gamma), & \ldots, & (c\kappa) \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ k_1, & (k\beta), & (k\gamma), & \ldots, & (k\kappa) \end{vmatrix}$$

we get

(6) . . . . $A . \Delta_1 = \nabla . \Delta$,

Subtracting, in the expression for ∇, the constituents of its first column multiplied by β_1 from the corresponding constituents of the second column, multiplied by γ_1 from those of the third column, and so on, and finally multiplied by κ_1 from those of the last column, we get by a known property of determinants and in virtue of (2)

(7) . . . . $$\nabla = \begin{vmatrix} a_1, & (a\beta)_1, & (a\gamma)_1, & \ldots, & (a\kappa)_1 \\ b_1, & (b\beta)_1, & (b\gamma)_1, & \ldots, & (b\kappa)_1 \\ c_1, & (c\beta)_1, & (c\gamma)_1, & \ldots, & (c\kappa)_1 \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ k_1, & (k\beta)_1, & (k\gamma)_1, & \ldots, & (k\kappa)_1 \end{vmatrix}$$

Now, D_1 being a certain minor of D, we denote by $D_1, D_2, \ldots, D_n$ the minors of D, which belong to the constituents of its first column. Then we have the well-known equations:

(8) . . . . $a_1D_1 + b_1D_2 + c_1D_3 + \ldots + k_1D_n = D$,

and

(9) . . . . . $$\begin{cases} a_2D_1 + b_2D_2 + c_2D_3 + \ldots + k_2D_n = o, \\ a_3D_1 + b_3D_2 + c_3D_3 + \ldots + k_3D_n = o, \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ a_nD_1 + b_nD_2 + c_nD_3 + \ldots + k_nD_n = o. \end{cases}$$

The first of the next following equations is obtained by addition of the equations

(9), after having multiplied them respectively by $\beta_2, \beta_3, \ldots, \beta_n$. In the same manner the second is obtained by means of the multipliers $\gamma_2, \gamma_3, \ldots, \gamma_n$ and so on until the last, which is obtained by using $\kappa_2, \kappa_3, \ldots, \kappa_n$ as multipliers. The equations, thus formed, are in virtue of the notations (1):

$$(10) \quad \ldots\ldots \quad \begin{cases} (a\beta)_1 D_1 + (b\beta)_1 D_2 + (c\beta)_1 D_3 + \ldots + (k\beta)_1 D_n = o, \\ (a\gamma)_1 D_1 + (b\gamma)_1 D_2 + (c\gamma)_1 D_3 + \ldots + (k\gamma)_1 D_n = o, \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ (a\kappa)_1 D_1 + (b\kappa)_1 D_2 + (c\kappa)_1 D_3 + \ldots + (k\kappa)_1 D_n = o. \end{cases}$$

From the equations (8) and (10) we get by elimination of $D_2, D^3, \ldots, D$,

$$\nabla . D_1 = D . \begin{vmatrix} (b\beta)_1, & (c\beta)_1, & \ldots, & (k\beta)_1 \\ (b\gamma)_1, & (c\gamma)_1, & \ldots, & (k\gamma)_1 \\ \ldots & \ldots & \ldots & \ldots \\ (b\kappa)_1, & (c\kappa)_1, & \ldots, & (k\kappa)_1 \end{vmatrix}$$

The last determinant in the second member of this equation is $= A_1$, in virtue of the well-known fundamental theorem about the change of rows into columns. The last equation, therefore, gives—

$$\nabla . D_1 = D . A_1,$$

whence, because by supposition the identity (5) holds, we get

$$\nabla = D . \Delta_1 .$$

Substituting this expression for ∇ in (6), there results

$$A = D . \Delta, \; q.e.d.$$

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18. *On the Motion of Two Cylinders in a Fluid.* *By* W. M. HICKS, *M.A.*

The motion of two infinite parallel cylinders in an infinite fluid, and the motion of one cylinder inside another full of fluid, were considered. In the second case, when the inside cylinder ($rad = b$) moved as a pendulum about the axis of the bounding one ($rad = a$), it was shown that the time of vibration was changed in the ratio

$$\left(\frac{T^1}{T}\right)^2 = \frac{1}{M - M_1} \left\{ M + 2M_1 \frac{L}{3 - 2x + x^2} \right\},$$

where M, M_1 are the masses of unit of length of the cylinder, and of the fluid displaced thereby; $x = \dfrac{a}{a-b}$ and L depends on the distance between the centres.

In the particular case where the inside cylinder touches the outside throughout the motion it was shown that

$$L = 1 + 2x^2 \frac{d^2}{dx^2} \log \Gamma(1 + x)$$

tables of which function are given by Legendre and De Morgan.

The more general problem was then discussed, and formulæ obtained for the motion of an infinite fluid in which two cylinders rest, and in which a source of fluid exists. Thence the velocity potential for any motion of the cylinders was deduced, and the kinetic energy of the fluid. It was shown that (u, u'; v, v', being the velocities along and perpendicular to the line joining the centres of the cylinders), the kinetic energy was—

$$2T = Pu^2 + (\pi a^2 + P)v^2 + P^1 u'^2 + (\pi b^2 + P^1)v'^2 + 2L(vv' - uu'),$$

where

$$P = 2\pi a^2 \gamma(\theta, \theta_1),$$

$$P^1 = 2\pi b^2 \gamma\left(\frac{1}{\theta} \cdot \theta_2\right),$$

$$L = 2\pi ab\gamma^1(\theta),$$

in which

$$\gamma(\theta,\theta_1)\equiv(\theta_1^2-1)^2\Sigma_1^\infty\frac{\theta^{2m}}{(\theta_1^2\theta^{2m}-1)^2},$$

$$\gamma^1(\theta)\equiv(\theta_1^2-1)(\theta_2^{-2}1)\Sigma_1^\infty\frac{\theta^{2m-1}}{(\theta^{2m}-1)},$$

$$\theta\equiv\frac{\theta_1}{\theta_2},$$

and $\theta_1 \cdot \theta_2$, depending only on the radii of the cylinders and the distances of their centres, may be expressed in various forms—*e.g.*, if e_1 e_2 are the angles subtended by the two cylinders, at the line where their radical plane cuts the plane of their axes,

$$\theta_1=\cot\tfrac{1}{4}e_1,\quad \theta_2=\cot\tfrac{1}{4}e_2.$$

Or again, if r be the distance of their centres,

$$\theta_1=\frac{\sqrt{\{(r+a+b)\ (r+a-b)\}}+\sqrt{\{(r-a+b)\ (r-a-b)\}}}{\sqrt{\{\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ \}}-\sqrt{\{\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ \}}}$$

$$\theta_2=\frac{\sqrt{\{(r+a+b)\ (r-a+b)\}}-\sqrt{\{(r+a-b)\ (r-a-b)\}}}{\sqrt{\{\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ \}}+\sqrt{\{\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ \}}}$$

the cylinders being external. If one is inside the other, this form is only slightly modified.

These formulæ are applicable to the case of one cylinder in a fluid bounded by an infinite plane, by putting in them $b-a, \theta_2=\frac{1}{\theta_1}$ $v^1=v$, $u^1=u$; but the properties of the fluid motion deduced from these formulæ were not discussed.

TUESDAY, AUGUST 20, 1878.

The Section divided itself into two departments for Astronomy and Physical Science.—See p. 486 for the letter.

The following Papers were read in the Department of Astronomy:—

1. *Report of the Committee on Luminous Meteors. By* JAMES GLAISHER, *F.R.S.* See Reports, p. 258.

2. *Report of the Committee on the Tides in the English Channel.* See Reports, p. 217.

3. *On an Equatorial Mounting for a Three-Foot Reflector. By* the EARL OF ROSSE.

4. *On the Tides of the Southern Hemisphere and of the Mediterranean. By* Capt. EVANS, *R.N., and* Sir WILLIAM THOMSON, *LL.D.*

On the coasts of the British Islands and generally on the European coasts of the North Atlantic and throughout the North Sea, the tides present in their main features an exceptional simplicity, two almost equally high-waters and two almost equally low-waters in the twenty-four hours, with the *regular* fortnightly inequality of spring tides and neap tides due to the alternately conspiring and opposing actions of the moon and sun, and with large *irregular* variations produced by wind. Careful observation detects a small "diurnal" inequality (so called because it is due to tidal constituents having periods approximately equal to twenty-four hours lunar or solar), of which the most obvious manifestation is a difference at certain times of the month and of the year between the heights of the two high-waters of the twenty-four hours, and at intermediate times a difference between the heights of the two low-waters.

In the western part of the North Atlantic and in the North Sea this diurnal inequality is so small in comparison with the familiar twelve-hourly or "semi-diurnal" tides that it is practically disregarded, and its very existence is scarcely a part of practical knowledge of the subject; but it is not so in other seas. There is probably no other *great* area of sea throughout which the diurnal tides are practically imperceptible and the semi-diurnal tides alone practically perceptible. In some places in the Pacific and in the China Sea it has long been remarked that there is but one high water in the twenty-four hours at certain times of the month, and in the Pacific, the China Sea, the Indian Ocean, the West Indies, and very generally wherever tides are known at all practically, except on the ocean coasts of Europe, they are known to be not "regular" according to the simple European rule, but to be complicated by large differences between the heights of consecutive high-waters and of consecutive low-waters, and by marked inequalities of the successive intervals of time between high-water and low-water.

On the coasts of the Mediterranean generally the tides are so small as to be not

			SOUTHERN
			Freemantle, Western Australia, Lat 32° 3′ S., Long. 115° 45′ E. Year 1873–74. I=27° 8, $\nu=+6^{\circ}.5$
S Speed of semi-diurnal $2(\gamma-\eta)=30^{\circ}$ per hour.	Mean solar	Diurnal	$R_1=0\ 039$ ft. $\epsilon_1=59^{\circ}.7$
		Semi-diurnal	$R_2=0.145$ ft. $\epsilon_2=291^{\circ}.9$
		Quarter-diurnal	$R_4=0.001$ ft. $\epsilon_4=71^{\circ}.6$
M Speed of semi-diurnal $2(\gamma-\sigma)=28^{\circ}.984$ per hour.	Mean lunar	Diurnal	$R_1=0.059$ ft. $\epsilon_1=349^{\circ}.2$
		Semi-diurnal	$R_2=0.154$ ft. $\epsilon_2=287^{\circ}.2$
		Ter-diurnal	$R_3=0\ 008$ ft. $\epsilon_3=219^{\circ}.1$
		Quarter-diurnal	$R_4=0\ 009$ ft. $\epsilon_4=262^{\circ}.4$
K Speeds γ and $2\gamma=15^{\circ}.041$ and $30^{\circ}.082$ per hour.	Luni-solar-declinational	Diurnal	$R_1=0.611$ ft. $\epsilon_1=304^{\circ}.8$
		Semi-diurnal	$R_2=0.051$ ft. $\epsilon_2=296^{\circ}.6$
O Speed $(\gamma-2\sigma)=13^{\circ}.943$ per hour.	Lunar-declinational	Diurnal	$R_1=0.430$ ft. $\epsilon_1=286^{\circ}.0$
P Speed $(\gamma-2\eta)=14^{\circ}.959$ per hour.	Solar-declinational	Diurnal	$R_1=0.156$ ft. $\epsilon_1=296^{\circ}.7$
L Speed $(2\gamma-\sigma-\varpi)=29^{\circ}.528$ per hour.	Smaller lunar-elliptic	Semi-diurnal	$R_2=0.011$ ft. $\epsilon_2=150^{\circ}.3$
N Speed $(2\gamma-3\sigma+\varpi)=28^{\circ}.440$ per hour.	Greater lunar-elliptic	Semi-diurnal	$R_2=0.040$ ft. $\epsilon_2=341^{\circ}.1$
Q Speed $(\gamma-3\sigma+\varpi)=13^{\circ}.399$ per hour.	Greater lunar-elliptic declinational	Diurnal	$R_1=0.114$ ft. $\epsilon_1=284^{\circ}.9$

HEMISPHERE		MEDITERRANEAN				
		Toulon, Lat. 43° 7′ N., Long. 5° 55′ E.				
Port Louis, Mauritius, Lat. 20° 9′ S., Long. 57° 31′ E. Year 1838–39. 1=28°·6; $v=-1°·5$	Port Louis, Berkeley Sound, East Falkland, Lat. 51° 29′ S., Long. 58° 0′ W. Year 1842, from May 10 to September 8, and from November 14 to December 15. 1=25°·6; $v=-11°·3$	Year 1847. 1=18°·6; $v=-4°·6$	Year 1848. 1=18°·5; $v=0°·7$	Year 1853. 1=24°·8; $v=+12°·1$	Marseilles, Lat. 43° 18′ N.; Long. 5° 22′·5 E. Year 1850–51. 1=21°·7; $v=+12°·4$	Malta, Lat. 35° 55′ N.; Long. 14° 30′ E. 1=24°·6; $v=+12°·2$
0·013 ft. 31°·8	0·289 ft. 25°·1	0·42 cm. 39°·3	0·28 cm. 14°·9	0·29 cm. 5°·6	0·57 cm. 48°·1	0·10 in. 161°·6
0·331 ft. 26°·0	0·492 ft. 195°·3	2.70 cm. 254°·3	2·74 cm. 216°·3	2·74 cm. 219°·8	2·37 cm. 246°·6	1·44 in. 100°·2
0·003 ft. 115°·6	0·007 ft. 64°·2	0 05 cm. 306°·1	0·05 cm. 259°·9	0·06 cm. 297°·7	0·08 cm. 276°·9	0·01 in. 36°·7
0·008 ft. 174°·8	0·052 ft. 347°·7	0·11 cm. 223°·0	0·09 cm. 303°·7	0·47 cm. 12°·3	0·16 cm. 83°·1	0·07 in. 268°·4
0·417 ft. 22°·8	1·530 ft. 155°·4	5·45 cm. 253°·9	7·04 cm. 244°·8	5·75 cm. 242°·4	6·87 cm. 229°·9	2·36 in. 94°·8
0·016 ft. 166°·9	0·018 ft. 339°·7	0·15 cm. 166°·3	0·08 cm. 183°·4	0·13 cm. 174°·0	0·15 cm. 187°·7	0·02 in. 207°·7
0·004 ft. 295°·2	0·066 ft. 352°·7	0·40 cm. 347°·5	0·61 cm. 24°·1	0·33 cm. 329°·0	0·62 cm. 3°·0	0·03 in. 354°·5
0·236 ft. 119°·7	0·350 ft. 29°·2	2·98 cm. 165°·3	3·23 cm. 165°·8	3·67 cm. 191°·9	3·29 cm. 187°·6	0·41 in. 51°·9
0·121 ft. 21°·2	0·160 ft. 189°·4	0·68 cm. 251°·4	0·37 cm. 250°·6	0·80 cm. 272°·5	0·52 cm. 267°·0	0·38 in. 127°·3
0·165 ft. 99°·4	0·481 ft. 13°·7	1·26 cm. 129°·8	1·68 cm. 124°·2	1·88 cm. 99°·0	1·85 cm. 97°·1	0·30 in. 72°·4
0·056 ft. 131°·7	0·141 ft. 86°·7	1·25 cm. 178°·6	1·29 cm. 175°·8	1·25 cm. 179°·4	1·19 cm. 182°·4	0·13 in. 57°·9
0·024 ft. 18°·7	0·060 ft. 132°·8	0·21 cm. 254°·1	0·33 cm. 223°·5	0·21 cm. 235°·3	0·22 cm. 274°·5	0·25 in. 116°·0
0·132 ft. 31°·9	0·332 ft. 128°·3	1·53 cm. 223°·4	1·61 cm. 234°·3	1·39 cm. 223°·1	1·36 cm. 222°·7	0·37 in. 116°·0
0·028 ft. 79°·2	... ...	0·38 cm. 42°·0	0·17 cm. 48°·8	0·19 cm. 32°·7	0·32 cm. 18°·4	0·08 in. 58°·5

perceptible to ordinary observation, and nothing, therefore, has been hitherto generally known regarding their character. But a first case of application of the harmonic analysis to the accurate continuous register of a self-recording tide-gauge (published in the 1876 report of the B.A. Tidal Committee) has shown for Toulon a diurnal tide amounting on an average of ordinary midsummer and mid-winter full and new moons to nearly $\frac{4}{5}$ of the semi-diurnal tides; and the present communication contains the results of analysis showing a similar result for Marseilles; but, on the other hand, for Malta, a diurnal tide (similarly reckoned), amounting to only $\frac{1}{4\frac{1}{2}}$ of the semi-diurnal tide. The amount of semi-diurnal tide is nearly the same in the three places, being, at full and new moon, about seven inches rise and fall.

The present investigation commenced in the Tidal Department of the Hydrographic Office, under the charge of Staff-Commander Harris, R.N., with an examination and careful practical analysis of a case greatly complicated by the diurnal inequality presented by tidal observations which had been made at Freemantle, Western Australia, in 1873–74, chiefly by Staff-Commander Archdeacon, R.N., the officer in charge of the Admiralty Survey of that Colony. The results disclosed very remarkable complications, the diurnal tides predominating over the semi-diurnal tides at some seasons of month and year, and at others almost disappearing and leaving only a small semi-diurnal tide of less than a foot rise and fall. These observations were also very interesting in respect to the great differences of mean level which they showed for different times of year, so great that the low-waters in March and April were generally higher than the high-waters in September and October. The observations were afterwards, under the direction of Captain Evans and Sir William Thomson, submitted to a complete harmonic analysis, worked out by Mr. E. Roberts. Not only on account of the interesting features presented by this first case of analysis of tides of the southern hemisphere, but because the south circumpolar ocean has been looked to, on theoretical grounds, as the origin of the tides, or of a large part of the tides, of the rest of the world, it seemed desirable to extend the investigation to other places of the southern hemisphere for which there are available data. Accordingly the records in the Hydrographic Office of tidal observations from all parts of the world were searched; but besides those of Freemantle, nothing from the southern hemisphere was found sufficiently complete for the harmonic analysis except a year's observations of self-registering tide-gauge at Port Louis, Mauritius, and personal observations made at regular hourly, and sometimes half-hourly, intervals for about six months (May to December) of 1842, at Port Louis, Berkeley Sound, East Falkland, under the direction of Sir James Clark Ross. These have been subjected to complete analysis.

So also have twelve months' observations by a self-registering tide-gauge during 1871–72 at Malta, contributed by Admiral Sir A. Cooper Key, K.C.B., F.R.S.

Tide-curves for two more years of Toulon (1847 and 1848), in addition to the one (1853), and for Marseilles for a twelvemonth of 1850–51, supplied by the French Hydrographic Office, have also been subjected to the harmonic analysis.

These results, both for the southern hemisphere and the Mediterranean, will form the subject of a paper which Captain Evans and Sir William Thomson hope to communicate to the Royal Society in the course of the coming session. In the meantime the numbers resulting from the harmonic analysis are submitted without further comments to the British Association for comparison with those for other places in previous Reports of the Tidal Committee. Those of them which represent the most important of the diurnal and semi-diurnal tides are shown in the following table, which includes also for immediate comparison the results for Toulon, 1853.

R in every case denotes, as in previous tables of the British Association Committee, the range of the particular tidal constituent on *either side of mean level*; so that $2R$ is the whole rise *from lowest to highest of the individual constituent.* (In comparing results with those shown in the Admiralty Tide Tables, it must be borne in mind that in the latter it is the rise above the level of ordinary low water spring tides that is given as "heights."

ϵ (technically called the epoch) is the angle, reckoned in degrees, which an arm revolving uniformly in the period of the particular tide has to run through till high water of this constituent, from a certain instant or era of reckoning defined for each constituent as follows:—

Definition of ϵ.*—To explain the meaning of the values of ϵ given in the following table of results, it is convenient to use Laplace's "astres fictifs," or ideal stars. Let them be as follows:—

M the "mean moon."

S the "mean sun."

K for diurnal tide, a star whose right ascension is 90°.

K for semi-diurnal tide the "first point of Aries," or ♈.

O a point moving with angular velocity 2σ, and having 270, of right ascension when *M* is in ♈.

Q a point moving with angular velocity $2\sigma - \varpi$, and 270° before *M* in right ascension when the longitude of *M* is half the longitude of the perigee.

P a point moving with angular velocity, 2η having 270° of right ascension when *S* is in ♈.

N a point moving with angular velocity, $\frac{3}{2}\sigma - \frac{1}{2}\varpi$, and passing alternately through the perigee and apogee of the moon's orbit when *M* is in perigee.

L a point moving with angular velocity, $\frac{1}{2}\sigma + \frac{1}{2}\varpi$, and passing alternately through 90° on either side of the perigee of the moon's orbit when *M* is in perigee.

The value of ϵ in each case above means the number of 360ths of its period which the corresponding tidal constituent has still to execute till its high-water from the instant when the ideal star crosses the meridian of the place. Thus if n denote the periodic speed of the particular tide in degrees per mean solar hour, its time of high-water is $\frac{\epsilon}{n}$, reckoned in mean solar hours after the transit of the ideal star.

In this definition, and in the table of results, the following notation is employed: †—

I to denote the mean inclination of the moon's orbit to the earth's equator during the time of the series of tidal observations included in each instance.

ν to denote the mean right ascension of the ascending node of the moon's orbit on the earth's equator during the same time.

γ to denote the angular velocity of the earth's rotation.

σ to denote the mean angular velocity of the moon's revolution round the earth.

η to denote the mean angular velocity of the earth round the sun.

ϖ to denote the angular velocity of progression of the moon's perigee.

"Speed" means the angular velocity of an arm revolving uniformly in the period of any particular tidal constituent; each angular velocity being reckoned in degrees per mean solar hour.

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5. *On the Influence of the Straits of Dover on the Tides of the British Channel and the North Sea.*‡ *By* Sir William Thomson.

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* This definition for the several cases of *K* diurnal, and *O*, *P*, *Q*, and *L* differs by 90° or 180°, or 270° from the definition given in the British Association Report (1876) for a reason obvious on inspection of Tables I. and II., pp. 304 and 305 of that report, which (except in respect to the longitudes of perigee and perihelion) show ϵ as previously reckoned for the several constituents.

† The values of I and ν are given to facilitate comparison with the equilibrium values of the several tidal constituents, according to Tables I. and II. of the British Association Tidal Committee's Report of 1876.

‡ See Section E., p. 639.

6. *On the Sun-heat received at the several Latitudes of the Earth, taking Account of the Absorption of Heat by the Atmosphere, with Conclusions as to the absolute Radiation of Earth Heat into Space, and the Minimum Duration of Geological Time. By* Professor S. HAUGHTON.

7. *Researches made at Dunsink on the Annual Parallax of Stars. By* Professor R. S. BALL.

8. *On the Precession of a Viscous Spheroid. By* G. H. DARWIN, *M.A., Fellow of Trinity College, Cambridge.*

I have been engaged for some time past in the investigation of the precession of a viscous spheroid, with the intention of seeing whether it would throw any light on the history of the earth in the remote past. As some very curious results have appeared in the course of the work, I propose to give an account of part of them to the British Association.

The subject is, however, so complex and long, that no attempt will be made even to sketch the analytical methods employed.

In a paper of mine, read before the Royal Society in May last, a theory was given of the bodily tides of viscous and imperfectly elastic spheroids; and this paper formed the foundation of the present investigation.

For convenience of diction, I shall speak of the tidally disturbed body as the earth, and of the disturbing bodies as the moon and sun; moreover, in all the numerical applications, the necessary data were taken from these three bodies.

An analytical investigation proved that—

The action of the sun and moon on the tides in the earth is such, that the obliquity to the ecliptic and the lengths of the day and month all become variable; the alteration in the length of the year remains, however, quite imperceptible.

The effect of the internal friction called viscosity is, that the bodily tides in the earth lag, and are less in height, than they would be if the earth were formed of a perfect fluid.

A general explanation was then given as to how the lagging of the tides produces the effects above referred to.*

And it appeared therefrom that when the viscosity is such that the bodily tides do not lag by very much, there is an increase of the obliquity to the ecliptic, a retardation of the earth's rotation, and a retardation of the moon's mean motion.

In this general explanation it was assumed that the lagging tides were exactly the same as though the earth were perfectly fluid or elastic, and as though the *tide-raising* moon were more advanced in her orbit than the true moon, whilst the moon which attracts the tidal protuberances was the true moon. That is to say, it was assumed that the tides raised were exactly the same as though the earth were perfect fluid, save that the time of high tide is late, and that the tides are reduced in height.

Now, although this serves in a general way to explain the phenomena which result from the supposition of the earth's viscosity, yet it is by no means an accurate representation of the state of the case.

In fact, the internal friction sifts out the whole tide-wave into its harmonic constituents, and allows the different constituents to be very differently affected as regards height and phase.

Thus the lagging tide-wave is not exactly such as the general explanation supposed, and the nearer does the spheroid approach to absolute rigidity the greater does the discrepancy become.

The general explanation is a very fair representation for moderate viscosities;

* See 'Nature,' September 26, 1878.

but for large ones it is so far from correct that the tendency for the obliquity to vary may become nil; and for yet larger ones the obliquity may tend to decrease.

A complete analysis of the state of things for various obliquities and viscosities shows that there is a great variety of positions of dynamical equilibrium, some of which are stable and some unstable.

Although there is all this variety with respect to the change of the obliquity, yet the tidal friction always tends one way, namely, to stop the earth's rotation.

It was shown in the general explanation that the effect on the moon is a force tangential to her orbit accelerating her linear motion, and thus indirectly retarding her angular motion. But it appears that for a very great degree of stiffness, and for large inclinations of the earth's axis to the ecliptic, this force on the moon may be actually reversed; so that the retardation of the moon's motion may actually be replaced by an acceleration. To a terrestrial observer, however, unconscious of the slackening of the earth's diurnal rotation, it would be indifferent whether the moon were undergoing true retardation or true acceleration; for in every case there would result an apparent acceleration of the moon's mean motion.

It is obvious from what has been said that we have the means of connecting the heights and lagging of the bodily tides in the earth with an apparent secular acceleration of the moon's mean motion. I have applied these ideas to the supposition that the moon has an apparent secular acceleration of $4''$ per century, and I find that if the earth were a homogeneous viscous spheroid, then the moon must be undergoing a secular *retardation* of $3''\cdot 6$ per century, while the earth (considered as a clock) must be losing 14 seconds in the same time. Under these circumstances, the effective rigidity of the earth must be so great that the bodily diurnal and semi-diurnal tides would be quite insensible; the *bodily* fortnightly tide would, however, be so considerable that the *oceanic* fortnightly tide would be reduced to one-seventh of its theoretical amount on a rigid nucleus, and the time of high water would be accelerated by three days.

The supposition that the earth is a nearly perfectly elastic body leads to very different results; which, however, I must now pass over.

From this and various other considerations I arrive at the conclusion that the apparent acceleration of the moon's motion affords no datum for determining the amount of tidal friction on the earth.

Sir William Thomson has made some interesting remarks about the probable age of the earth in connection with tidal friction, and he derived his estimate of the rate at which the diurnal rotation is slackening principally from the secular acceleration of the moon. He fully admitted that his data did not admit of precise results; but if I am correct in the present conclusion, it certainly appears that his argument must lose part of its force.

The investigation of the secular changes which such a system would undergo is surrounded by great mathematical difficulties, but I think that I have succeeded in surmounting them by methods, partly analytical and partly arithmetical.

In a communication of the present kind it would be out of place to consider the methods employed, and I will therefore only speak of some of the results.

There are two standards by which we may judge of the viscosity in the present problem; first, the ordinary one, in which it is asserted that it requires so many pounds of tangential stress to the square inch to shear an inch cube through so much in such and such a time; and secondly, when the viscosity is judged of by the amount by which the behaviour of the spheroid departs from that of a perfectly fluid one. A numerical value for this sort of measure is afforded by the angle by which the crest of the tidal spheroid precedes the moon, when the obliquity to the ecliptic is zero.

Now it appears that if the earth possessed a viscosity which was not at all great, as estimated by the tidal standard, yet the materials of the earth, when considered in comparison with the substances which we know, would be found to be a substance of very great stiffness—stiffer than lead, and perhaps nearly as stiff as iron. I see, therefore, no adequate reason why some part of the changes, which will be considered presently, should not have taken place during geological history.

The problem was solved numerically for a degree of viscosity which would make the changes proceed with nearly a maximum rapidity; estimated by the

tidal standard, this is neither a very great nor a very small viscosity, for the crest of the semi-diurnal tide precedes the moon by 17° 30′.

I found, then, that if the changes in the system are tracked back for 56 million years, we find the day reduced to 6 hours 50 minutes, the obliquity to the ecliptic 9° less than at present, and the moon's period round the earth reduced to 1 day 14 hours.

This very short period for the moon indicates of course that her distance from the earth is small. As the moon goes on approaching the earth, the problem becomes much more complex; and for periods more remote than 56 million years ago, I abandoned the attempt to obtain a scale of times. The solution up to this point shows that the times requisite for these causes to produce such startling effects are well within the time which physicists have admitted to have elapsed since the earth existed.

From this point in the solution the parallel changes of the obliquity, day and month, were traced without reference to time.

It appears, then (still looking backwards in time), that the obliquity will only continue to diminish a little more beyond the point already reached; for when the month has become equal to twice the day there is no longer any tendency for the obliquity to diminish, and for yet smaller values of the month the tendency is to increase again.

From this we learn that when the day is equal or less than half the month, the position of the earth's axis at right angles to the plane of the moon's orbit is one of dynamical stability. The whole decrease of obliquity from the present value back to the critical point, where the month is equal to twice the day, is 10°.

From this point in the solution back to the initial state to which the earth and moon are tending, the obliquity to the plane of the lunar orbit was neglected. I then found that the limiting condition, beyond which it was impossible to go, was one in which the earth and moon are rotating, fixed together as a rigid body in 5 hours and 40 minutes. This condition was also found to be one of dynamical instability, so that if the month had been a little shorter than the day, the moon must have fallen into the earth; but if the month had been a little longer than the day, the moon must have receded from the earth, and have gone through the series of changes which were traced backwards up to this initial condition.

This periodic time of the moon of 5 hours 40 minutes corresponds to an interval of only 6,000 miles between the moon's centre and the earth's surface. Moreover, if the earth had been treated as heterogeneous instead of homogeneous, this interval between the primeval earth and moon would have been yet further diminished, as also would be the common periodic time. The conclusion, therefore, appears to me almost irresistible, that if the moon and earth were ever molten viscous bodies, then they once formed parts of a common mass.

With respect to the obliquity of the ecliptic, the question is one of considerable difficulty; but on the whole I incline to the view that while a large part of the obliquity may be referred to these causes, yet that there remains an outstanding part which is not so explicable.

Besides the results of which the outlines have been given, I have obtained some others which, as I believe, will aid in the formation of a modified edition of the nebular hypothesis—such as some of the changes to which an annular satellite would be subjected.

One of the collateral results which appeared in considering the secular changes of such a system [as the earth, moon, and sun, was that a large amount of heat would have been generated in the interior of the earth by means of friction. If, then, it is permissible to suppose that any considerable part of these changes have taken place during geological history, Sir William Thomson's problem of the secular cooling of the earth would require some modification.

The magnitude of the undertaking has not allowed me time as yet to apply these ideas to the questions of the eccentricity and inclination of the orbit of the satellite, nor to the cases of other planets besides the earth.

I think, however, that I see in Asaph Hall's wonderful discovery of the Martian Satellites a confirmation of this theory. Their extreme minuteness has, I

think, preserved them as a standing memorial of the primitive period of rotation of that planet. The Uranian system, on the other hand, appears, at least at first sight, a stumbling-block.

It is easy to discern in the planetary system many *veræ causæ*, which tend to change its configuration; but it is in general very hard to give any quantitative estimate of their effects.

It will have been seen that, in the investigation of which I have given an imperfect account, free scope has been given to speculation, but that speculation has been governed and directed in every case by appeal to the numerical results of a dynamical problem, and I therefore submit that it stands on a different footing from the numerous general speculations to which the nebular hypothesis has given rise.

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9. *On the Limits of Hypotheses regarding the Physical Properties of the Matter of the Interior of the Earth.* By Professor HENRY HENNESSY, *F.R.S.*

The author pointed out that every hypothesis of a philosophical character must conform to the condition of not being in contradiction to observed facts. The known physical properties of solids, liquids, and gases were referred to, and the bearings of such properties on the problems regarding the earth's structure were indicated. Mathematical inquiries, which started from supposing an incompressible liquid enclosed in a compressible and elastic envelope, could not lead to conclusions at all invalidating the opinion held by the author. He supported his views by deductions drawn from the observed properties of solids and liquids, and not from hypotheses of unreal and impossible properties of these substances such as formed the basis of the elaborate and learned mathematical labours of Sir William Thomson and Mr. Darwin. The views he had long since maintained in opposition to the conclusions of the late Mr. Hopkins regarding the earth's solidity had been discussed in a manner satisfactory to the author in the Academy of Sciences of Paris,* when he had formally laid his views before that scientific body, and his subsequent studies had led him to maintain the correctness of his original views respecting the earth's internal fluidity.†

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10. *On the Climate of the British Islands.* By Professor HENRY HENNESSY, *F.R.S.*

The author laid before the Section the results of the discussion on temperature observations made at a great many stations in Great Britain and Ireland tabulated in isothermal groups. He pointed out the lines of equal temperature over the British Isles deduced from these observations conformed to the same general law as that which he had communicated to the Association at former meetings—namely, that the isothermal lines are similar to the coast lines, and that some of the former may be even closed curves. He showed that an untrue representation of temperature would be produced by introducing the artificial correction of 1° Fahrenheit for every 300 feet above the sea level derived from observations in balloons; and he explained that it was owing to this untenable mode of altering the results of observations of temperature that some recent maps deviate from those he had originally produced. Among the absurd consequences of this artificial alteration of observed results, he remarked that actual temperatures were in some instances raised from 43° 6′ to 47° 3′, from 43° 3′ to 47° 1′, from 42° 2′ to 46° 6′, and from 44° 4′ to 48° 8′. A map of the distribution of plants would in these cases present a semi-alpine or semi-arctic flora in contact with isothermal lines corresponding to the flora of temperate regions. He maintained that the general law of distribution of temperature in islands surrounded by warm water currents, which he had

* "Remarques à propos d'une communication de M. Delaunay sur les résultats fournis par l'Astronomie concernant l'épaisseur de la croûte solide du globe."—'Comptes Rendus, Inst. France,' 1871, p. 250.

† This Paper is published *in extenso* in the 'Philosophical Magazine' for Oct. 1878.

long since announced, had been more firmly established and consolidated by accumulated observations. The paper was illustrated by maps showing the distribution of isothermal lines in harmony with Professor Hennessy's law of distribution.

11. *On a new Method of maintaining the Motion of a Free Pendulum in vacuo. By* DAVID GILL.

12. *On Space Numbers: an Extension of Arithmetic. By* B. H. HINTON.

In the Department of Physical Science the following Papers were read:

1. *Report of the Committee for commencing Secular Experiments on the Elasticity of Wires.* See Reports, p. 103.

2. *A New Form of Polariscope. By* Professor WILLIAM GRYLLS ADAMS, *M.A., F.R.S.*

This instrument has been constructed by Mr. S. C. Tisley, on the principle communicated by the author to the Physical Society of London (see 'Proc. Phys. Soc.' Vol. i. p. 152, and 'Phil. Mag.,' July 1875). The advantages gained by it are—(1) an extensive field of view; (2) an accurate means of measuring the rings and the separation of the optic axes in biaxal crystals.

The polarizer is a Nicol's prism, capable of giving a clear parallel beam of polarized light $2\frac{1}{2}$ inches in diameter; this beam falling on a system of lenses, is brought to a focus at the point where the crystal is placed. The beam, after passing through the crystal, is rendered parallel again by another system of lenses, and passes through a similar Nicol's prism and another lens for focusing upon the screen. The peculiarity of the instrument consists in the arrangement of the two central lenses, one on either side of the crystal. These two lenses are plano-convex—very nearly hemispheres—and, with their flat surfaces inwards, form the two sides of a box to hold oil or a liquid; they are so placed that their convex surfaces form portions of the same spherical surface. The crystal is placed in the box at the centre of curvature of the spherical surfaces of the two lenses.

For measurement, the crystal is immersed in oil, and adjusted to its right position by a cup and socket motion; the box and the crystal with it is then turned about an axis at right angles to the direction of the axis of the beam of light, and thus, either of the optic axes of any crystal may be made to coincide with the centre of the field of view, the angle through which the box is turned being measured to minutes by means of a circle attached to it, and a vernier attached to the fixed stand supporting the instrument. A table-polariscope on the same principle has also been made by Herr Schneider, of Vienna, from the description given in the 'Philosophical Magazine.' By means of these instruments, both optic axes of topaz are brought well into the field of view at the same time; and by turning the circle which carries the box any two directions in the crystal within an angle of 90° of one another can be brought into the centre of the field of view, and the angle between them accurately measured. The field of view is only limited by the internal reflection at the plane surface of the lenses next to the rotating lenses.

3. *A New Determination of the Number of Electrostatic Units in the Electro-Magnetic Unit. By* W. E. AYRTON *and* J. PERRY. Telegram and Letter to Sir W. THOMSON from Professor W. E. AYRTON.

THE RED SEA, August 3.

MY DEAR SIR WILLIAM,—From Singapore I sent you the following telegram on the 13th July from Professor Perry and myself.

"Kindly inform British Association that air-condenser measured magnetically and statically gives mean value ratio of these units (29·80) twenty-nine point eight nought ohms; Foucault's velocity light."

In the autumn of this year I propose communicating a full account of this investigation to the Physical Society, or the Society of Telegraph Engineers, or otherwise as you may advise; but I thought that, as the British Association Committee had for so long busied itself with the determination of electrical units, you might deem the result of this investigation of Mr. Perry and myself worthy of a preliminary notice at the meeting of the Association to be held this year at Dublin. Not being sure that I should arrive in Europe in time to reach Dublin at the commencement of the meeting, although I hope to be present during the last three or four days, I took the liberty of sending you the telegram quoted above.

The result we have obtained for "v" is the more interesting, inasmuch as, without any bias being given to any one of our experiments, the mean value is identically the same as that obtained by M. Foucault for the velocity of light, whereas all previous determinations of the number of electrostatic units in an electromagnetic unit have led to results differing considerably from Foucault's velocity.

It appeared to Mr. Perry and myself that the method best suited for the accurate determination of "v" consisted in measuring the capacity of an air-condenser—
1. electromagnetically, by the swing of the needle of a ballistic galvanometer; and
2. electrostatically, by a measurement of the linear dimensions of the condenser, since the equation connecting these capacities—

$$s = v^2 S,$$

s being the absolute electrostatic capacity,
S „ „ electromagnetic capacity,

leads to an equation involving only the *square root* of a resistance.

Two difficulties of course presented themselves in this investigation—difficulties that it took us many months to overcome, labouring as we were under the disadvantage of experimenting in a country like Japan. They were—

1. To obtain a large air condenser, of which the plates had sufficiently true surfaces that the electrostatic capacity could be accurately measured, at any rate when the plates were not nearer than half a centimetre to one another.

2. To obtain a galvanometric arrangement of sufficient sensibility to measure the small capacity of such an air condenser, and sufficiently ballistic that the air damping should be almost inappreciable.

A full description of the condenser we employed (and which had a guard ring, and all the different arrangements we could think of for obtaining accurate results) will accompany the account of the investigations to which I have referred. It is sufficient here to mention that the errors arising from the surfaces of the condenser plates not being true planes were practically eliminated by capacity experiments being made with successive adjustments of the condenser-plates, a different set of points in the upper plate being each time brought to the fixed distance from the lower plate.

The arrangement of a ballistic galvanometer to fulfil the two conditions mentioned in (2) was very troublesome. I made several astatic needles, none of which satisfied us, and we were beginning to fear my departure from Japan would necessitate the abandoning of the investigation. At last, however, an astatic combination containing (40) forty small magnets (and of which a description will accompany the paper) gave satisfactory results, and I obtained three excellent sets of observations on June 18, June 23, and June 25, when my departure put an

end to further investigation. The *mean* values obtained for "*v*" on each of these three days were:

	29·74 ohms	June 18.
	29·95 „	„ 23.
	29·72 „	„ 25.
Final mean	29 80	

It will be observed that the greatest difference between any one of the three daily means and the final mean is only about half per cent. The final number 298·0 million metres per second (and which represents the mean of ninety-eight discharges of the air condenser) may, I think, be regarded as correct to, at any rate, one per per cent., and is exactly equal to M. Foucault's velocity of light.

In the astatic combinations I employed prior to June 18 I used eight needles, and weighted the lower set of needles with pieces of brass, so as to give it a barrel shape, but the results were unsatisfactory, as there was either not sufficient delicacy or else too much damping. Consequently, all the numbers obtained prior to June 18 have been abandoned. On June 18 were made the first set of experiments with the forty-magnet astatic combination; the idea of this arrangement being to make an approximately spherical mass of little magnets all slightly separated from one another, and all previously magnetised to saturation. As it would have been too difficult to make this entire sphere all of magnets, I finished it off with segments cut from a little wooden sphere. But the half Napierian logarithmic decrement was 0·12095, and we thought this too high. Consequently, in the interval from June 18 to June 23, I took this astatic combination down and replaced the segments of the wooden sphere by segments of a small leaden hemispherical *shell*. This diminished the half Napierian logarithmic decrement to 0·07825, and with a periodic time of 39·5 seconds I obtained most consistent results. But on the other hand, the close agreement of the results obtained on June 18 and on June 25, leads one to conclude that the wooden segments were quite satisfactory, and that replacing them with the leaden shell was unnecessary.

The table on the accompanying sheet gives the value of the most important constants employed. The battery consisted of 382 perfectly new Daniell's cells in series, and the galvanometer had a resistance of 20,000 ohms. All resistances were compared with a new German-silver wire box, recently received from Messrs. Elliott, London.

Determination of the Number of Electrostatic Units in an Electromagnetic one.

Date	Area of condenser plate in square centimetres	Distance between the plates, in centimetres	Weight of the Astatic Combination, in grammes	Periodic time, in seconds	Half the Napierian logarithmic decrement	Mean value of "*v*"	Remarks
June 18	1324·96	1·024	2·15	25·3	0·12095	29·74	Ninety-eight discharges of the air condenser
„ 23	1323·14*	0·7728	3·4	39·5	0 07825	29 95	
„ 25	1323·14	0·7728	3·4	42·2	0·081865	29·72	

June 18. The lower set of needles was weighted with segments cut from a small wooden sphere.

June 23 and after. The lower set of needles was weighted with segments cut from a small leaden spherical shell.

Number of magnets in astatic combination, 40.

Number of new Daniell's cells in series, 382.

* The distance between the upper condenser plate and the guard ring was slightly increased by diminishing the size of the plate to avoid the possibility of loss of electricity.

The values obtained for "v" are (as far as I am aware) up to the present time as follows:—

MM. Weber and Kolraush	31·074 ohms.
Sir W. Thomson	28·2 "
Professor C. Maxwell	28·8 "
Professors Ayrton and Perry	29·80 "
Velocity of light—M. Foucault	29·8 "

During the last twelve months we have been hard at work with the determination of the electromotive force of contact of metals and liquids, using a new apparatus. Some of the results are, we venture to think, most interesting; for instance, the electromotive force of contact of hot and cold mercury, *no other conductors being in contact with either mercury*; the electromotive force of contact of a cold metal and hot mercury, no third conductor being in contact with either, &c., &c. The determination of the electromotive force of contact of the pairs of constituents of Mr. Latimer Clark's constant mercurous sulphate cell was most laborious, and occupied me weeks, in consequence of the difference of potential that exists between the body of the mercurous sulphate paste and the layer of water that floats on the surface. However, a forlorn hope kept me hard at it, and I am glad to say at last I was successful in getting good results. We have gone over all the old ground that furnished the basis of our former paper, as well as much new ground.

Believe me to remain, dear Sir William, sincerely yours,

Professor Sir William Thomson, F.R.S., &c. W. E. Ayrton.

It has been decided that the full account of the above determination of "v" shall be given to the Society of Telegraph Engineers during the winter 1878–79.

4. *On Apparatus employed in Researches on Crookes's Force.* *By* Richard J. Moss, *F.C.S.*

The author exhibited and described the apparatus which had been employed by himself and Mr. G. J. Stoney, F.R.S., in their researches on Crookes's Force. Early in 1876 they devised a means of ascertaining the existence of a reaction between the blackened vanes of a radiometer and the sides of the surrounding glass envelope. A flat piece of elder-pith with one side blackened was attached by one end to the inner surface of a small flask. A light glass arm suspended in the flask from a silk fibre carried a disk of thin microscope glass which could be brought opposite the blackened pith, and within a millimetre or two of it. When the flask was exhausted it was observed that the pith when illuminated repelled the glass disk, even when the tension of the residual air was equal to 7 m.m. of mercury. Having obtained this result, another apparatus was constructed, with the view of obtaining comparative measurements of the force at various tensions with a given distance between the glass and the pith; and at various distances with a given tension of the residual gas. This apparatus is figured and described in the 'Proceedings of the Royal Society,' 1877, p. 553. It was found that in an atmosphere of hydrogen a Crookes's force was manifested at a distance of even 10 m.m., when the tension of the residual gas was as much as 5 m.m. of mercury. Within certain limits the force was found to vary about inversely as the tension; and at a given tension the variations produced by alterations in the distance between the pith and the glass were nearly inversely as the distance until it exceeded 20 m.m. (half the diameter of the containing tube), when the force remained almost constant, even at a distance of 100 m.m., the maximum of which the apparatus admitted.

5. *On Spheroidal Drops.* *By* Richard J. Moss, *F.C.S.*

According to Mr. G. J. Stoney's recently published theory of the spheroidal state, the drops are supported by the pressure which is exerted between hot and cold surfaces when they are within a certain distance from one another, depending on the

length of the free path of the molecules enclosed between the surfaces, and on the difference of temperature of the latter. By duly observing the conditions of this theory it was found possible to support a spheroid of ether on a surface of the same liquid for upwards of an hour and a half. The author has shown* that the supporting layer of gas need not necessarily consist of the vapour of the spheroid, or of the liquid upon which it floats; since melted paraffin, which showed no diminution in weight even when heated for an hour *in vacuo* at the temperature of boiling water, readily yields spheroids at ordinary atmospheric tensions when its temperature is 80–90° C. If the drops are kept cool by means of a gentle current of air, they continue to float for a considerable time.

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6. *On the Spherical Class-Cubic with Three Single Foci.* *By* Henry M. Jeffery, *M.A.**

1. Let the three foci A, B, C be a quadrant apart, so that the triangle of reference (ABC) is tri-rectangular.

A group of class-cubics thus constituted may be thus denoted by line coordinates:—

$$2\,dpqr + (ap + \beta\,q + \gamma\,r)\,(p^2 + q^2 + r^2) = o,$$

where d is the parameter of the group, (a, β, γ) the satellite-point.

2. When there are inflexional cubics in the group, the locus of the satellite-point may be thus found, by equating the invariants to zero.

$$S \equiv \left\{ d^2 - (a^2 + \beta^2 + \gamma^2) \right\}^2 - 12da\beta\gamma = o,$$

$$-\frac{T}{8} \equiv \left\{ d^2 - (a^2 + \beta^2 + \gamma^2) \right\}^3 + 90d^3a\beta\gamma - 54d^2(\beta^2\gamma^2 + \gamma^2a^2 + a^2\beta^2)$$
$$+ 18da\beta\gamma\,(a^2 + \beta^2 + \gamma^2) = o.$$

The eliminant of d is found to be of the eighteenth degree:—

$$27\,(a^2 + \beta^2 + \gamma^2)\,(\beta^2\gamma^2 + \gamma^2a^2 + a^2\beta^2)^4 - 12 \times 81a^2\beta^2\gamma^2\,(\beta^2\gamma^2 + \gamma^2a^2 + a^2\beta^2)^3$$
$$- 8 \times (27)^2(a^2 + \beta^2 + \gamma^2)^2(\beta^2\gamma^2 + \gamma^2a^2 + a^2\beta^2)^2a^2\beta^2\gamma^2$$
$$- 112 \times 17 \times 27(a^2 + \beta^2 + \gamma^2)(\beta^2\gamma^2 + \gamma^2a^2 + a^2\beta^2)a^4\beta^4\gamma^4 + 16 \times (27)^2(a^2 + \beta^2 + \gamma^2)^3a^4\beta^4\gamma^4$$
$$+ 16 \times (17)^3a^6\beta^6\gamma^6 = o.$$

If this equation be arranged according to the powers of a, its highest term is

$$(27)^2(\beta^2 - \gamma^2)^4a^{10} + \ldots$$

The curve has four loops at each of its three foci and their antipodes, at which the tangents intersect at right angles. It is petal-shaped, like the Rhodoneæ of Abbate Guido Grandi. (Gregory's 'Examples of the Diff. and Int. Calc.,' fig. 40.)

3. There are seven critic lines at the most.

For a critic value, $S^3 + \left(\frac{T}{8}\right)^2 = o$. This function will be found to be of the seventh degree in the parameter (d).

The theorem may be also thus established.

By partial differentiation with respect to the variables (p, q, r),

$$a\,(p^2 + q^2 + r^2) + 2p(ap + \beta q + \gamma r) + 2dqr = o.$$
$$\beta\,(p^2 + q^2 + r^2) + 2q(ap + \beta q + \gamma r) + 2dpr = o.$$
$$\gamma\,(p^2 + q^2 + r^2) + 2r(ap + \beta q + \gamma r) + 2dpq = o.$$

Hence the critic lines are determined symmetrically by cubics with collinear foci (p, q, $ap - \beta q$).

$$\frac{ap}{-p^2 + q^2 + r^2} = \frac{\beta q}{p^2 - q^2 + r^2} = \frac{\gamma r}{p^2 + q^2 - r^2}$$

* 'Proceedings of Royal Dublin Society,' vol. i. (new series), p. 87.

Their common tangents are seven by a well-known theorem (Salmon's 'Higher Algebra,' Art. 248.)

4. A moveable point (P) lies on AD, arcs (or *in plano*, right lines) connect P with two other points B, C: the envelope of the bisector of the angle BPC is one of the preceding cubics. Similarly, the bisectors of the angles AQC, BRA, if Q, R move on BD, CD, envelope the other cubics, which determine the critic lines by their mutual combination. This is an extension of a theorem of Plücker.

5. In the most general case, where ABC may have any position on the sphere, the critic lines are thus determined:—

$$\frac{ap}{-apP+bqQ+crR}=\frac{\beta q}{apP-bqQ+crR}=\frac{\gamma r}{apP+bqQ-crR},$$

where $P\equiv ap-bq\cos C-cr\cos B$, and Q, R have similar values. But the equation and form of the locus of the satellite, when there are inflexional values in the group of class-cubics, is not here determined.

6. By reciprocating, the critic centres of a group of spherical order-cubics are determined to be seven by the intersecting cubics—

$$\frac{p\alpha}{6V-2a\alpha(a\alpha+b\beta\cos c+c\gamma\cos b)}=\ldots\ldots=\ldots\ldots$$

In plano, as is well known, these degenerate into three critic centres, formed by the intersection of three hyperbolæ. For then $\cos a=\cos b=\cos c=1$: $6V=\Sigma(a^2\alpha^2+2bc\beta\gamma\cos a)=4\Delta^2$, and the cubics become hyperbolæ:

$$\frac{p\alpha}{-a\alpha+b\beta+c\gamma}=\frac{q\beta}{a\alpha-b\beta+c\gamma}=\frac{r\gamma}{a\alpha+b\beta-c\gamma}.$$

7. *On a Cubic Surface referred to a Pentad of Co-tangential Points.* By HENRY M. JEFFERY, M.A.

1. A cubic surface may be generated as the locus of the foci in involution of all the transversals, concurrent in a fixed point, which meet a system of quadrics or conicoids, intersecting in a quadro-quadric curve. This is an extension of Cremona's method of generating plane cubics to solid geometry. Dr. Salmon's process leads to the same analytical expression. In such a system of conicoids, the locus of the conic curves of contact of enveloping cones, with a common vertex, is a cubic surface.

2. All the pole planes of the fixed point, with respect to the conicoids, intersect in a straight line PQ, which is one of the 27 lines on the cubic. If the system of conicoids be referred to their self-conjugate tetrahedron, and if the fixed point be E, the centre of the inscribed sphere (1,1,1,1), the five triple tangent-planes through PQ touch the cubic in the four vertices of the tetrahedron and in E the centre. Consider any pair of lines, as AP, AQ, forming a triangle APQ with PQ. Then, beside the original plane APQ through each of the lines AP, AQ, four more triple tangent planes can be drawn: in all nine such planes. The same is true of the planes through the pairs of lines at B,C,D,E, which constitute with PQ triple tangent planes. Thus the 45 planes are exhibited. Again, besides the line PQ and the five pairs of intersecting lines, which meet PQ in ten points, there are 16 lines, which may be determined in five different ways. Four of the five triple tangents through each of the lines AP, AQ (exclusive of the common plane APQ), determine 8 lines each, the number required. The same process may be used with the same results, if the triple planes through the lines intersecting in B,C,D,E be used. The arrangement of these planes and lines, whose discovery by Professors Cayley and Salmon constituted an epoch in Solid Geometry, may be compared for simplicity with Professor Schafli's double-sixers, and Dr. Hart's cubical system of grouping.

3. The analogues to Maclaurin's theorem on tetrads do not present themselves. But points on the cubic may be thus multiplied.

Transversals through a fixed point P on the cubic pass through the vertices A,B,C,D,E, which constitute the pentad of co-tangential points, and intersect the

surface in A′,B′,C′,D′,E′. If these five points be joined with the former five in pairs, the points of intersection lie on the curve and are four, Q,R,S,T; and six other points are constituted on the curve by the intersections of AB′, A′B; AC′, A′C; AD′, A′D; BC′, B′C; BD′, B′D: and CD′, C′D. Call these six points (a,b), (a,c), (a,d), (b,c), (b,d), (c,d).

It will be found that these 21 points lie on 40 chords, viz., A,B,C,D,E on 8 chords each, and the other 16 points on 5 chords each, according to the following table:—

P,A,A′	Q,A,E′	R,A,(c,d)	S,A,(b,d)	T,A,(b,c)	B′,A,(a,b)	C′,A,(a,c)	D′,A,(a,d)
P,B,B′	Q,B,(c,d)	R,B,E′	S,B,(a,d)	T,B,(a,c)	C′,B,(b,c)	A′,B,(a,b)	D′,B,(b,d)
P,C,C′	Q,C,(b,d)	R,C,(a,d)	S,C,E′	T,C,(a,b)	D′,C,(c,d)	B′,C,(b,c)	A′,C,(a,c)
P,D,D′	Q,D,(b,c)	R,D,(a,c)	S,D,(a,b)	T,D,E′	B′,D,(b,d)	A′,D,(a,d)	C′,D,(c,d)
P,E,E′	Q,E,A′	R,E,B′	S,E,C′	T,E,D′	(a,b),E,(c,d)	(a,c),E,(b,d)	(b,c),E,(a,d)

4. Let the quadro-quadric curve be denoted by the equations to two conicoids of the system:—

$$l_1a^2+m_1\beta^2+n_1\gamma^2+r_1\delta^2=o.$$
$$l_2a^2+m_2\beta^2+n_2\gamma^2+r_1\delta^2=o.$$

Let the equation to a transversal through a fixed point (f,g,h,k) be:—

$$\frac{a-f}{\lambda}=\frac{\beta-g}{\mu}=\frac{\gamma-h}{\nu}=\frac{\delta-k}{\rho}=\mathrm{R}.$$

For the segments of its distances from the conicoids:—

$$l_1(f+\lambda\mathrm{R})^2+m_1(g+\mu\mathrm{R})^2+n_1(h+\nu\mathrm{R})^2+r_1(k+\rho\mathrm{R})^2=o=\mathrm{U}.$$
$$l_2(f+\lambda\mathrm{R})^2+m_2(g+\mu\mathrm{R})^2+n_2(h+\nu\mathrm{R})_2+r_2(k+\rho\mathrm{R})^2=o=\mathrm{V}.$$

The following equation denotes the foci of these lines in involution: if $\frac{\mathrm{R}}{\sigma}$ be written for R, and finally $\sigma=1$.

$$\frac{d\mathrm{U}}{d\mathrm{R}}\cdot\frac{d\mathrm{V}}{d\sigma}-\frac{d\mathrm{U}}{d\sigma}\cdot\frac{d\mathrm{V}}{d\mathrm{R}}=o.$$

This function yields on development:

$$\Sigma(l_1\mathrm{m}_2-l_2m_1)\ (\lambda g-\mu f)\ (f+\lambda\mathrm{R})\ (g+\mu\mathrm{R})=o.$$
$$\text{Or, }\Sigma(l_1m_2-l_2m_1)\ (ag-\beta f)\ a\beta=o.$$

This may be reduced to the form—

$$(l_1a^2+m_1\beta^2+n_1\gamma^2+r_1\delta^2)\ (l_2af+m_2\beta g+n^2\gamma h+r_2\delta k).$$
$$=(l_2a^2+m_2\beta^2+n_2\gamma^2+r_2\delta^2)\ (l_1af+m_1\beta g+n_1\gamma h+r_1\delta k).$$

The dual of this theorem (§ 1) may be noted.

If a system of conicoids be inscribed in a quadro-quadric torse, and if from each line of a fixed plane tangent planes are drawn to the conicoids, the envelop of the focal planes in involution of the system is a cubic class-surface.

5. The above equation may be obtained as the eliminant of a conicoid of the system, and the pole-plane of a fixed point.

$$(l_1-\lambda l_2)a^2+(m_1-\lambda m_2)\beta^2+(n_1-\lambda n_2)\gamma^2+(r_1-\lambda r_2)\delta^2=o.$$
$$\Sigma(l_1-\lambda l_2)af\quad o.$$

This is Dr. Salmon's method (§1), which seems capable of generating surfaces of any order or class from a surface of the next lower order or class.

6. In this investigation, $f=g=h=k$ or E is the fixed point, without loss of generality.

Professor Cayley's notation is adopted for the minors of the determinant:—

$$\left\|\begin{matrix}l_1, m_1, n_1, r_1\\ l_2, m_2, n_2, r_2\end{matrix}\right\|\quad\text{Thus 12 denotes}\quad\left|\begin{matrix}l_1, m_1\\ l_2, m_2\end{matrix}\right|,\quad 12+21=o.$$

The following relation subsists between the minors, as has been pointed out. ('Quarterly Journal of Mathematics,' vol. xv.)

$$23.41+31.42+12.43=o.$$

It will be convenient to denote by a, b, c, d, the sums of certain minors:

$$a = 12 + 13 + 14 : b = 21 + 23 + 24.$$
$$c = 31 + 32 + 34 : d = 41 + 42 + 43.$$

Then it will be seen that

$$\begin{aligned} a + b + c + d &= o. \\ 23a + 31b + 12c &= o. \\ 34b + 42c + 23d &= o. \\ 34a + 41c + 13d &= o. \\ 24a + 41b + 12d &= o. \end{aligned}$$

Hence the cubic under discussion may be written:

$$23\beta\gamma\ (\beta - \gamma) + 31\gamma a\ (\gamma - a) + 12a\beta\ (a - \beta) + 41a\delta\ (\delta - a) + 42\beta\delta\ (\delta - \beta) + 34\gamma\delta\ (\gamma - \delta) = o.$$

7. The equations to the tangent planes at the vertices of the tetrahedron and at E the centre, which constitute a pentad of points, are—

$$\begin{aligned} 12\beta + 13\gamma + 14\delta &= o. \\ 21a \qquad + 23\gamma + 24\delta &= o. \\ 31a + 32\beta \qquad + 34\delta &= o. \\ 41a + 42\beta + 43\gamma \qquad &= o. \\ aa + b\beta + c\gamma + d\delta &= o. \end{aligned}$$

These are fine triple tangent planes; and any two determine the line PQ on the cubic, through which they are drawn.

8. The equations to the pole-conicoids of the points of the pentad are—

$$\begin{aligned} 12\beta^2 + 13\gamma^2 + 14\delta^2 - 2a(12\beta + 13\gamma + 12\delta) &= o. \\ 21a^2 \qquad + 23\gamma^2 + 24\delta^2 - 2\beta(21a + 23\gamma + 24\delta) &= o. \\ 31a^2 + 32\beta^2 \qquad + 34\delta^2 - 2\gamma(31a + 32\beta + 34\delta) &= o. \\ 41a^2 + 42\beta^2 + 43\gamma^2 \qquad - 2\delta(41a + 42a + 43\gamma) &= o. \\ aa^2 + b\beta^2 + c\gamma^2 + d\delta^2 \qquad &= o. \end{aligned}$$

The four cones $(12\beta^2 + 12\gamma^2 + 12\delta^2 = o)$ and the like, belong to the same quadro-quadric, and the fifth pole-conicoid is a hyperboloid of one sheet whose asymptotic cone is inscribed in an orthogonal trihedral angle.

8. To determine the ten lines on the cubic which intersect in PQ.

The two lines AP, AQ, are obtained by the intersection of the tangent-plane and cone

$$12\beta + 13\gamma + 14\delta = o.$$
$$12\beta^2 + 13\gamma^2 + 14\delta^2 = o.$$

Their equations are—

$$\beta : \gamma : \delta :: 14 \pm \frac{u}{12} : 14 \mp \frac{u}{13} : -(12 + 13),$$

$$\text{if} \qquad u^2 + 12 \,.\, 13 \,.\, 14\ (12 + 13 + 14) = o.$$

Similar equations denote the other four pairs of lines.

9. To determine the eight triple tangent planes, four through AP, and four through AQ, other than PAQ; and the sixteen lines on the surface, eight of which intersect in AP, and eight in AQ, other than PQ and AQ or AP respectively.

$$\text{Write } g : h : k :: 14 \pm \frac{u}{12} : 14 \mp \frac{u}{13} : -(12 + 13):$$

so that $(h\beta - g\gamma = o)$ denotes the plane APD or AQD. Then, if ρ denote a parameter, the equation

$$\beta(12 + \rho h) + \gamma\,(13 - \rho g) + 14\delta = o$$

denotes any plane through AP or AQ.

For brevity, write the coefficients $\frac{12 + \rho h}{14} = p : \ \frac{13 - \rho g}{14} = q;$

the equation becomes $\qquad p\beta + q\gamma + \delta = o.$

Let this equation be combined with that to the cubic (§ 6.)

$$\begin{aligned}&\beta^2\gamma\,(23+42q+43p^2+2\,.\,42pq)+\beta\gamma^2(-23+43p^2+42q^2+2\,.\,43pq)\\&+\gamma^2\alpha\,(31+41q^2)+\gamma\alpha^2(-31+41q)+\alpha^2\beta(12+41p)\\&+\alpha\beta^2\,(-12+41p^2)+2\alpha\beta\gamma\,.\,41pq+\beta^3 42(p^2+p)+\gamma^3 43(q^2+q)=o.\end{aligned}$$

After rejecting the known factor $\beta h-\gamma g$, the conic of intersection is thus denoted.

$$-\alpha^2\rho+\frac{\beta^2}{h}42\,(p^2+p)-\frac{\gamma^2}{g}\,43(q^2+q)+\frac{\alpha\beta}{h}\,(-12+41p^2)$$

$$-\frac{\alpha\gamma}{g}(31+41q^2)+\beta\gamma\left(\frac{43p^2}{h}-\frac{42q^2}{g}+\frac{43.12}{14h}-\frac{42\;13}{14g}\right)=o.$$

This may assume the more tractable form :—

$$(41\alpha+42\beta+43\gamma)\left\{\frac{\beta}{h}\left(p^2+\frac{12}{14}\right)-\frac{\gamma}{g}\left(q^2+\frac{13}{14}\right)\right\}$$

$$+\frac{\rho}{14}\left(41\alpha^2+42\beta^2+43\gamma^2\right).$$

This ternary quadric may be resolved into linear factors if

$$42\,.\,43\left\{2\rho+\frac{14p^2+12}{h}-\frac{14q^2+13}{g}\right\}^2$$

$$=(41+42+43)\left\{\frac{43}{h^2}(14p^2+12)^2+\frac{42}{g^2}(14q^2+13)^2\right\}$$

where $14p=12+\rho h$, $14q=13-\rho g$.

This quartic yields four values of the parameter ρ, so that the equations are determined to eight triple tangent planes through A, since g, h have each two values dependent on the values of u.

The two preceding linear factors denote the traces on the co-ordinate plane ABC, or rather the planes through D and those traces of a pair of lines which intersect in AP or AQ. The four values of ρ yield sixteen in all—eight which meet in AP, and eight in AQ

To complete the investigation of the equations to the lines on the cubic, it would be necessary to combine another form of a tangent plane :—

$$12\beta+\gamma\,(13+\rho h)+\delta\,(14+\rho h)=o.$$

By proceeding as above, the rejection of the known factor $h\gamma+h\delta$, leads to the conic of intersection :—

$$(21\alpha+23\gamma+24\delta)\left\{\frac{\gamma}{h}\left(\mu^2+\frac{13}{12}\right)+\frac{\delta}{h}\left(\nu^2+\frac{14}{12}\right)\right\}$$

$$+\frac{\rho}{12}\left(21\alpha^2+23\gamma^2+24\delta^2\right)=o,$$

where for brevity $\mu=\dfrac{13+\rho h}{12}:\nu=\dfrac{14+\rho h}{12}.$

If this quadric be resoluble into linear factors

$$23\,.\,24\left\{2\rho+\frac{1}{h}\left(12\mu^2+13\right)+\frac{1}{h}\left(12\nu^2+14\right)\right\}^2$$

$$=(21+23+24)\left\{\frac{23}{h^2}\left(12\nu^2+14\right)^2+\frac{24}{k^2}\left(12\mu^2+13\right)^2\right\}.$$

The actual solutions of these quartics has not been attempted, since the auxiliary cubic is cumbrous; although we may infer from the circumstance, that the same sixteen lines may be determined indifferently from A, B, C, D, or E, that the expressions would be explicit. This quartic yields four values of ρ, which substituted in the preceding quadric, determine the projections on the co-ordinate plane ACD of four pairs of lines on the cubic which intersect in AP and four pairs

which meet in AQ. The equations to these traces, combined with the equations of the former traces on ABC, completely determine the lines.

10. The theorem of § 3 may be thus proved.

Let (f,g,h,k) denote P in the preceding tetrahedral system; then A′,B′,C′,D′,E′ have for their co-ordinates (F,g,h,k), $(f,G,h,k,)$, (f,g,H,k), (f,g,h,K): where

$$F+f=G+g=H+h=K+k=\frac{12g^2+13h^2+14k^2}{12g\ +13h\ +14k}=\ldots\ldots=\ldots\ldots$$

Then the coordinates of Q,R,S,T have this type:

$$(f,G,H,K),\ (F,g,H,K),\ (F,G,h,K),\ (F,G,H,k);$$

and the points (a,b), (a,c) ... have the type (F,G,h,k), (F,g,H,k).........

With these data the theorem is as readily established, as its Plane analogue 'Quarterly Journal of Mathematics,' vol. xv. p. 203.

8. *A New Form of Trap-Door Electrometer. By* Professor BARRETT.*

9. *On Unilateral Conductivity in Tourmaline Crystals. By* Professor SILVANUS P. THOMPSON *and* Dr. OLIVER J. LODGE.

The authors regarded the phenomena of pyroelectricity as exhibited by the tourmaline and other crystals as of the utmost significance in the theory of the relation of electricity to the particles of matter. Dr. Lodge had read a paper at the British Association Meeting at Glasgow on a mechanical model illustrating the flow of an electric current through a circuit of molecules. (See *Phil. Mag.*, Nov. and Dec. supp. 1876.)

The considerations therein advanced had led the authors independently to conclude that the phenomena of pyroelectricity could be explained if it could be shown that such crystals as were pyroelectric possessed *unilateral conductivity* (§ 25 of above paper). The term "unilateral conductivity" had been given by Dr. A. Schuster to a phenomenon of some obscurity observed by him in certain cases, and which formed the subject of a communication to a former meeting of the Association. The term "unilateral conductivity" was defined as follows:—If the conductivity of a substance in a given direction between two points A and B was greater when the flow was in the direction from A to B than when the flow was in the direction from B to A, then such a substance was said to possess unilateral conductivity.

It had been argued by the first-named of the authors of the paper that if the tourmaline possessed a unilateral conductivity for electricity, it would also be found to possess unilateral conductivity for heat, since the researches of Tait and Kohlrausch had shown that the two conductivities are comparable in almost all points of analogy. The experimental research, therefore, had divided itself into two branches—a thermal and an electrical.

Owing to the difficulty of procuring suitable specimens of tourmaline crystal a delay of some months occurred, but eventually this difficulty was overcome through the kindness of Professor N. Story Maskelyne. Other crystals had also been procured from France.

The method first suggested for comparing the two heat-conductivities as measured in opposite directions along the axis of the crystal was that of De Senarmont. A slice of the crystal was cut with parallel faces containing the crystallographic axis, and having been covered with a film of wax, or with Meusel's double iodide of copper and mercury, was heated from a point by a hot wire. When the experiment was rapidly made, the elliptical isothermal line marked out by the melted wax or the blackened iodide, was found to be displaced from the

* A Model was exhibited.

centre, and this displacement was towards the analogous pole; showing that while the temperature was rising, the conductivity in that direction was greater than in the opposite direction. When, however, the experiment was done slowly with a thicker crystal, so that thermal equilibrium was gradually attained, no such unilateral effect could be observed. Rough preliminary experiments showed the unequal semi-axes minor to have a ratio of about 10 to 12, but there was considerable discordance between the various results.

A calorimetric method was next adopted to measure the flow of heat across a thin wall of tourmaline cut normally to its crystallographic axis. The thin slice was fixed between two similar portions of glass tubing, either end of which could therefore be made to hold a weighed quantity of mercury whilst steam was blown up into the other. In this way the heat which passed upwards through the crystal when one surface was maintained at 100° could be measured in either direction. Experiments were made alternately, the times required to heat the mercury through a given range of temperature being compared in the two cases. To eliminate error, after half the experiments had been made the crystal slice was itself reversed between the glass tubes. The results, which exhibited as fair agreement with one another as could be expected, showed, as before, that the conductivity for heat was greater towards the analogous pole so long as the temperature of the crystal was rising.

In respect of the electrical conductivity, time had only permitted a few preliminary experiments. The slice of crystal was heated in a steam bath. A five microfarad condenser was charged through the crystal for one minute with 10 or 12 Daniell's cells, and the condenser was then discharged through a sensitive Thomson galvanometer of 7000 ohms resistance. The limit of the very slight swing was accurately observed, and then the operation was repeated with the tourmaline electrically reversed. This was repeated alternately. When the temperature was rising a difference between the two swings was perceived; also when the temperature was falling there was a difference in the other direction. But these must have been chiefly due to the electromotive force, so-called, of the crystal. When the temperature was steady not the slightest difference could be perceived. The authors would wish, before being satisfied with this result, to heat the tourmaline to higher temperatures, and to try a much higher electromotive force—say that of 1000 cells.

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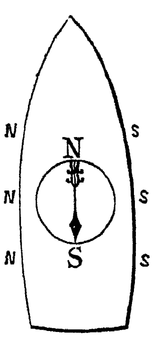
10. *On Gaussin's Warning regarding the Sluggishness of Ships' Magnetism.* *By* Sir WILLIAM THOMSON, *F.R.S.*

(Practical Rule and Caution.)

1. After steering for some time on westerly courses, expect 1 (*a*) westerly error if you turn to the north, 1 (*b*) or easterly error if you turn to the south.



2. After steering for some time on easterly courses, expect 2 (*a*) easterly error if you turn to the north, or 2 (*b*) westerly error if you turn to the south.

The diagram representing case 1 (*a*) illustrates the physical explanation: N. and S. representing the north and south points of the compass card (or "*true south*" and "*true north*" poles of its needles), and the small letters *s*, *s*, *s*, true southern polarity, and *n*, *n*, *n*, true northern polarity, induced in the port and starboard ends of deck beams, and port and starboard sides of ship, while steering east, and remaining for some time after she has been turned to north.

In the Admiralty 'Compass Manual,' Gaussin's warning is given with reference to the direction of swinging, in correcting the compass by magnets, according to Airy's first method. In the Reports of the Liverpool Compass Committee, and in Mr. Towson's 'Information for Masters and Mates regarding Ships' Magnetism,' instances of perplexing changes in the compass are given, and are referred to the same cause. The "sluggishness" of ships' magnetism,

according to which it depends generally in part on the influence experienced some time before the time of observation, and not wholly on the influence at the time, seems to have been first definitely noticed and discussed scientifically by Sir Edward Sabine, in his analysis of the results of the magnetic observations in the Antarctic exploring expedition of Sir James Ross, in the *Erebus* and *Terror*, in the years 1839–43.

The practical rule and caution given above is of great importance in the navigation of iron ships. The amount of the error which may be found cannot be predicted for ships in general, nor for any particular ship, except after much experience and careful observation. A small effect of two or three degrees,* such as that referred to in the Admiralty Manual as found in M. Gaussin's experience, may be observed in the course of quietly swinging a ship by hawsers or steam tugs. If the ship under weigh is steamed round on the different courses, the amount of the "Gaussin error" may generally be greater than if she is hauled round by warps; but we must not be sure that it will be so, because the *shake* of the screw, which enhances the magnetization on the east or west courses, may shake it out again before the observation is made on the north or south courses. A good practical rule in correcting the compass is, after having got it quite correct on the north and south course, correct just half the error which is found after that on the south or north course in the regular swinging of the ship.

The warning at the head of this article is particularly important for ships of war after firing guns when on easterly or westerly courses, if the course is then changed to north or south, and particularly if after the firing the change of course is effected under canvas, without the shaking of the ship's magnetism produced by the engines and screw.

The warning is also very important for ships steaming through the Mediterranean eastwards or westwards, and then turning south, through the Suez Canal, or north round Cape St. Vincent; and for ships steaming eastward from America, and then turning northwards or southwards into St. George's Channel.

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11. *On the Electrical Properties of Bees' Wax and Lead Chloride.* *By* Professors J. PERRY *and* W. E. AYRTON.

Professor Ayrton commenced by noting the close way in which investigations in the various branches of physical science were linked one with another, and by remarking that experiments on electric absorption ought to have no less interest for the scientific engineer than those on the increasing strain of materials under constant mechanical stress had for the electrician. He next explained how, in consequence of the absorbed charge in water being immeasurably greater than the surface charge, the direct method of determining experimentally the specific inductive capacity employed by Mr. Perry and himself, in their experiments on 'Ice as an Electrolyte,' failed to give the result equal to the square of the index of refraction for light of infinitely long waves, and he suggested that the method recently employed by Mr. Gordon for measuring the specific inductive capacity of solids with very rapidly reversed charges might possibly, if applied to water, give an answer approximately more equal to the square of the index of refraction; however, he was inclined to think that, since Mr. Gordon's method for solids gave (after the application of the proper correcting factor for the thickness of the dielectric) numbers closely agreeing with the received specific inductive capacities, there existed no known method for correctly ascertaining the electric capacity of a liquid.

For although a condenser might be made of opposed metallic plates separated by a space almost entirely filled with a liquid dielectric, which did not, however, touch either plate, and although, according to the ordinary nomenclature, the two plates in such an arrangement would be said to be insulated from the water and

* Much greater effects than this are actually found in the cases of gun practice, and of long steaming on easterly or westerly courses referred to below.

from one another, still, as explained in their paper on the 'Viscosity of Dielectrics,' a succession of rapidly reversed charges would be accompanied by *true electric conduction*; in fact, that it would be well worthy of consideration whether the explanation of the result which Mr. Gordon had brought to their notice at this meeting, viz., that his new method of measuring specific inductive capacity of solid dielectrics had given the old results, might not be found to consist in this *conduction* —this viscous conduction he might term it, although in reality there was but one kind of conduction, the conversion of electric energy into heat—for this conduction would occur unequally in the two apparently balanced condensers, since the two dielectrics varied in viscosity, consequently the balance of capacities was not a real one.

Nevertheless Professor Ayrton thought it highly important that careful experiments should be made, both with constant and with rapidly reversed charges, on the inductive phenomena observed in such a water condenser as he had described.

The abnormal rise in the specific inductive capacity of bees' wax, on solidifying, which the experiments of Professor Perry and himself had shown, coincided with an increase in the index of refraction; he regarded this as furnishing an important addition to the experimental proof of Professor Clerk Maxwell's electro-magnetic theory of light, and he hoped that some of those philosophers of Trinity College, Dublin, who had so successfully turned their attention to the elucidation of the molecular vibrations causing Crookes's force, would give their views on the molecular vibrations accompanying wave motion and electric induction.

He thought that the experiments described in the paper on bees' wax and lead chloride showed, in a sufficiently satisfactory way, that, where the resistance of an electrolyte diminished by electrification, it was due to the electromotive force employed being sufficiently great to decompose the damp in the pores of the electrolyte; but, in view of the fact that the resistance of water itself increased by electrification, it seemed to follow that the products of the decomposition of the damp must act chemically on the solid electrolyte and cause deterioration, and hence a smaller specific resistance. But if there were deterioration we should expect that the specific resistance of the material would steadily diminish day by day, a result that was not obtained in the experiments of Professor Perry and himself, on bees' wax at any rate, as will be seen on examining the table given in their paper in the 'Philosophical Magazine' for August. He therefore concluded that further experiments on electrolytes, in which resistance diminishes by electrification, were necessary to make the explanation quite complete.

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12. *Theory of Voltaic Action.** *By* J. Brown.

The author described some experiments made with a Volta's condenser having plates of iron and copper, and with a ring half of copper and half iron, which show that the difference of electric potential of these metals when in contact depends on the atmosphere surrounding them.

While in the ordinary atmosphere iron is positive to copper, in an atmosphere of hydrogen sulphide copper is positive to iron. These effects are explained by the chemical theory of electricity, as due in the first-mentioned case to the superior chemical affinity of the iron for the oxygen of the watery vapour, and other oxygen compounds present in the air; in the second, to the greater affinity of the copper for the sulphur of the hydrogen sulphide.

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13. *Mutual Action of Vortex Atoms and Ultramundane Corpuscles. By* Professor G. Forbes.

It is well known that amongst the numerous theories which have dealt with the *form* of an atom, there is only one which is in accordance with the properties

* A description of the experiments is given in the 'Phil. Mag.,' August, 1878.

which we know atoms to possess. It was originated by Sir William Thomson, whose conclusions, based on the researches of Helmholtz on fluid motion, may be briefly summarised.

According to this view the whole of space is filled with a frictionless fluid, and material atoms are portions of this fluid, having a species of rotational motion, which, as Helmholtz proved, must continue for ever.

The best analogy to this universal plenum and to these vortex atoms is the behaviour in an atmosphere of "smoke-rings," such as may be blown from the mouth of the smoker of tobacco, from the funnel of a locomotive, or from the mouth of a cannon. Such smoke-rings have remarkable properties, which are due, not to the smoke, which merely renders them visible, but to their internal motions.

Such "vortex rings" can travel with great rapidity. They can vibrate, they can rebound from each other with perfect elasticity, and, supposing that such action takes place in a frictionless fluid, they would be no less indestructible than uncreatable by mechanical means.

It is also well known that Le Sage of Geneva conceived a kinetic theory of gravitation, which has been adopted by Sir William Thomson. According to Le Sage, the whole of space is filled with small particles, which he calls ultramundane corpuscles, flying with enormous velocity through every point of space in every direction. These penetrate even the void spaces between atoms, so that of those which shower upon the earth perhaps not more than 1 in 10,000 have their velocity diminished by collision. The others pass right through the earth. Owing to these collisions, however, a smaller number of ultramundane corpuscles are to be found moving in the direction from the earth than towards it. Thus the earth acts as a shield, protecting surrounding bodies from the shower of ultramundane corpuscles in that direction. Hence the moon, and bodies on the earth's surface, are battered by ultramundane corpuscles most in the direction towards the earth. This force, driving bodies towards the earth, explains terrestrial gravitation. Similarly, all bodies are driven towards each other with a force varying as the product of the masses Sir William Thomson supposes ultramundane corpuscles to be vortex rings with no hole in the centre and elongated, like a serpent rushing forwards and always turning inside out, spitting its inwards out at its mouth, and absorbing its skin at the other end. Collisions with vortex atoms would not result in a destruction of velocity and consequent enormous generation of heat, but energy of translation is converted into some other form of energy, perhaps energy of vibration.

However artificial these hypotheses may appear at first sight, the more they are studied the more satisfactory are they. They are the only suggestions of the kind which are in any way tenable, and they serve at least the part of working hypotheses. Some remarkable and unforeseen consequences follow from the coexistence of such vortex atoms and ultramundane corpuscles as Thomson has conceived. The following facts seem to follow from the laws of hydro-kinetics:—

1. When a body is heated, and the vortex atoms are rushing about, their mutual collisions originate vibrations in themselves which, when they are free, have a definite period, or periods, depending upon the nature of each vortex atom.

2. When an ultramundane corpuscle passes such a vibrating atom, the successive approaches and recessions of the atom to and from the corpuscle impress upon that corpuscle a wave-form whose dimensions depend partly on the velocity of the corpuscle, partly on the vibrations of the atom.

3. When a corpuscle so stamped continues its progress through the frictionless fluid before mentioned, the position of the wave-marks remain fixed relatively to the corpuscles, without being affected by its internal motions.

4. If such a marked corpuscle in its flight passes the neighbourhood of a cold atom, *i.e.*, one which is not vibrating, and if that atom be capable of vibrating in the same period as the original atom which impressed the wave-trace, then the wave-trace on the corpuscle will, on passing the atom, cause it to vibrate in the same manner as the original atom.

The phonograph supplies a happy illustration of these processes:—

1. When the membrane, with needle attached, is vibrating we have the analogue of a hot atom.

2. If during this vibration the tin-foil on the cylinder be passed in front of the needle, the vibrating needle stamps a wave-trace on the tin-foil.

3. The tin-foil preserves this trace during its subsequent motion.

4. If at any subsequent time the stamped tin-foil passes in front of the needle when it is not vibrating (the analogue of a cold atom), the needle is caused to vibrate in the same period as before.

These analogies would be more perfect if the needle were set into vibration by being attached to a tuning-fork of definite period of vibration.

It appears, then, that the co-existence of such vortex atoms and ultramundane corpuscles as Sir William Thomson has devised leads to the conclusion that hot bodies must emit radiations which may be absorbed by cold bodies. The question naturally arises, Can this action be the keystone to a new theory of light? Can the phenomena of reflection, refraction, interference, diffraction, and polarisation be explained by this kind of action? In answer to these questions it can at present only be said that the germs of a complete theory of light do exist in this speculation.

SECTION B.—CHEMICAL SCIENCE.

PRESIDENT OF THE SECTION.—Professor Maxwell Simpson, M.D., F.R.S., F.C.S.

THURSDAY, AUGUST 15, 1878.

Professor MAXWELL SIMPSON gave the following Address:—

MY position here is a highly honourable, but by no means a comfortable one. Naturally, you expect to hear from me something new about the science which occupies the attention of this section, and I have the miserable feeling that I must disappoint you. How can I possibly find a fact in chemistry with which you are not already acquainted? If, in order to cater for you, I go to France, Germany, Russia or America, I find the abstractors of the Chemical Society have been there before me, and have swept everything of value into their Journal. Chemists are now kept perfectly acquainted with the progress of science in every part of the world, and therefore the *raison d'être* of this address, so far as announcing the discoveries of the year is concerned, has passed away. I therefore propose, instead of giving you a concentrated essence of the last twelve numbers of the 'Journal of the Chemical Society,' to bring before you the claims of this science to a place in general education, and the claims of original research to a place in the curriculum for higher degrees in our Universities.

I have been devoted to chemistry all my life. It has been my business and my pleasure. The longer I live the more deeply am I impressed with the advantages to be derived from its study, and I am anxious that these advantages should be shared by the rising generation.

Whether we take into account the value of the knowledge acquired, the discipline of the intellectual faculties in acquiring that knowledge, or the effect on the character, surely we have a right to give the study of this science a prominent place in our schools and colleges. It would be difficult to over-estimate the value and extent of the knowledge we derive from chemistry. Without it we can know nothing about the air we breathe, the water we drink, or the food we eat; we cannot understand the processes of combustion, respiration, fermentation, putrefaction, or the endless chemical changes which are continually in operation around us, and which affect our lives for good or for evil. In a word, the whole of the phenomena of nature must for ever remain to us, more or less, an inscrutable mystery.

Again, is it not desirable that we should have some acquaintance with the chemical arts, from which we derive so many of our comforts and luxuries? Should we not know something of the arts of photography, dyeing, metallurgy—something of the manufacture of glass and china, and of the thousand beautiful things that are constantly in our hands? Not only is the knowledge we obtain from chemistry very considerable in itself, but it furnishes us with a key, which enables us to unlock vast stores of knowledge, contained in several other sciences—these are, Physics, Geology, Mineralogy, Physiology, and I may now add, Astronomy. Physics and chemistry are so intimately connected that it is difficult to say

where the one begins and the other ends. The help that chemistry gives to physics is shown by the numbers of chemists who have distinguished themselves as physicists. I may mention a few belonging to our own time—Andrews, Bunsen, Faraday, Frankland, Graham, Guthrie, and Regnault.

With regard to mental discipline, the mind of the student is exercised in both the inductive and deductive methods of reasoning. His original faculties are stimulated by the consciousness that he can in many cases readily test the worth of his ideas by experiment. With inexpensive apparatus and a good balance, the intelligent student can make out for himself some of the laws and many of the facts of the science, and it may be, also, add to them. He glides insensibly from the known to the unknown. Indeed his spirit of inquiry demands, in most cases, to be curbed rather than spurred. Some students are constantly finding out new methods of analysis or discovering the precious metals in impossible places.

The readiness with which we can cross over into the *terra incognita* of chemistry, and make little explorations there, constitutes in my opinion the great charm of this science, and, to a great extent, its value as an educational agent. What I wish to insist upon is, that the student of chemistry can reach the field of original work sooner than the student of most other sciences. Once he commences original research, the developement of his intellectual faculties rapidly progresses. His imagination is daily exercised in propounding new theories, and devising experiments in order to ascertain their truth or falsehood. And what more valuable intellectual training can there be than the habit of subjecting our ideas to the test of inexorable experiment? In the world outside chemistry, we are, alas! too ready to take things for granted. The chemist's motto is, *Prove all things*. The ancients adopted a different method: they assumed certain principles and reasoned from them. They therefore did little in science.

Chemistry promotes in a remarkable manner accuracy, thoroughness, and circumspection. An organic analysis requires six weighings: if any one of these is inaccurate, the results are worthless. A qualitative test carelessly applied may cause us, in a research, to waste months in the pursuit of a phantom or Will-o'-the-Wisp which can have no corporeal existence. If we have to employ absolute alcohol in our experiments, we must not be satisfied with going through the ceremony of making it absolute, but we must assure ourselves that it *is* absolute. Unless we are sure of every step in our research, our results become doubtful, and therefore of no value.

On the circumspection, also, of the original worker large demands are made. The avenues by which error may creep in and vitiate his results are very numerous. These he must foresee, and endeavour to close up. Laboratory work teaches us to use our senses aright, sharpens our powers of observation, and prevents us from reasoning rashly from appearances. It also promotes manual dexterity, and trains the hands to work in subordination to the head.

Perhaps in no other science is the student so deeply impressed with the order and economy of nature, the immutability of her laws, and the exactness of her operations. These impressions will, no doubt, in after life impart seriousness to his character, and save him from the adoption of many a wild theory.

I come now to the effect of original work on the character. Many virtues are necessary to the chemist—courage, resolution, truthfulness, and patience. He is often obliged to perform experiments which are attended with great danger, and no man can hope to fight long with the elements without carrying away many a scar. Sometimes fatal accidents occur. Many years ago, Mr. Hennel, of the Apothecaries' Hall, London, lost his life by the explosion of a fulminating powder which he was preparing for the East India Company. And many of us recollect the sad death of young Mr. Chapman, a distinguished chemist whom I had the pleasure of knowing, who was literally blown to atoms while working in the Hartz Mountains on a new dynamite which he had himself discovered. I must tell the ladies, however, that accidents are not always so disastrous, but that often one may escape with merely the loss of an eye. But the chemist must not be discouraged by fear of accident, neither must he be disheartened by the temporary failure of his experiments, nor at the slowness of his processes. Bunsen was obliged to evaporate 44 tons of the waters of the Dürcheim springs in order to obtain 200 grains of his new metal,

Cæsium. It took Berthelot several months to form, by a series of synthetical operations, an appreciable quantity of alcohol from water and carbon, derived from carbonate of baryta. Many years ago, in the laboratory of Wurtz—my honoured master—a poor student, whom I knew, was carrying from one room to another a glass globe, which contained the product of a month's continuous labour, when the bottom of the globe fell out and the contents were lost. Nothing daunted, he recommenced his month's work, and brought his research to a successful issue.

Above all things, the chemist must be *true*. He must not allow his wishes to bias his judgment or prevent him from seeing his researches in their true light. He must not be satisfied that his results appear true, but he must believe them to be true; and having faithfully performed his experiments, he must record them faithfully. He may often be obliged to chronicle his own failures and describe operations that tell against his own theories, but this hard test of his truthfulness he must not shrink from.

But I must not weary you with the virtues of the chemist. If I have succeeded in showing that the pursuit of this science tends largely to develope the intellect and discipline the character, I think I have done something for chemistry. We are told by Bishop Butler that "habits of virtue acquired by discipline are improvement in virtue, and improvement in virtue must be advancement in happiness."

I am glad to see that the importance of original research as a part of higher education is at last beginning to be recognised in this country. The Royal University Commission at Oxford has recently recommended that candidates for the higher degrees in science shall in that University be required in future to work out an original investigation. In Germany, where education has been so long and so well understood, original work has been, for at least the last half century, a *sine quâ non* for a degree. Another admirable rule exists in that country, the adoption of which in Great Britain might go far to wash out the stain from our islands, of not having contributed our fair quota to the advancement of human knowledge. It is this—the Germans make a point of securing invariably, that their scientific chairs shall be filled by men who have already distinguished themselves by their discoveries. The professor, on his appointment, naturally desires to continue his investigations, and endeavours to secure, and usually succeeds in securing, the assistance of his pupils. This is a mutual advantage. The professor is able to do more work for science, and the student, on his part, learns to conduct for himself an original investigation. Hence there is always a rising generation of original workers in Germany, who turn out papers more or less meritorious with the rapidity of a Walter's press. They are stimulated by the hope of one day arriving themselves at a professor's chair, the path to which they are well assured is only through the toilsome field of original work. But I must not wrong the German student by the implication of a purely selfish motive in his work. His labour is one of love, and his ambition, for the time at least, is bounded by the desire to *do something* for science. And from a multitude of such enthusiasts the great professors come. Great mountains are only found in mountainous countries.

I find myself insensibly led to speak of the encouragement of research in this country; and although it has been very largely discussed in scientific circles, I will venture to add a few words. To promote original work here, I believe it is indispensable that our professors should be well paid. It would save them from the necessity of supplementing their incomes by commercial analyses, and thus enable them to devote their spare time to original work. And to secure that they shall have spare time, I would like to see in every laboratory a competent assistant, who would be able occasionally to take up the professor's lectures, should he be engaged in important work. There are many around me who know how very exacting original investigation is, and how necessary it is, at times, to be able to work on without interruption; bits and scraps of time being of no value. I am glad to see that the Oxford Commission also recommends the appointment of well-paid assistants. Well-paid professorships and well-paid assistantships would be attractive prizes for our students to work up to; and if it were clearly understood that the only way to these prizes was through original investigation, we should very soon have an army of zealous and competent workers.

The plan of appointing a staff of original workers unconnected with teaching

has been proposed; but I do not approve of it. The original worker is, as a rule, the best teacher, and the rising generation of students should not be deprived of the advantage of his instruction. Moreover, as I said before, the professor may be greatly assisted by his pupils.

No doubt the Government grant fund does a good deal for science, but the field of its operations is, under present conditions, limited. Professors, as a rule, are so occupied with teaching that they cannot avail themselves of the fund; and of those students who might be competent and willing, very few can afford to do so. Instead of trusting to the precarious and insufficient support of the fund, they must endeavour to settle themselves permanently in life.

It is much to be regretted that the Universities of Oxford and Cambridge, with such splendid revenues at their disposal, should contribute so little to the advancement of physical science. I hope the day is not far distant when the fellowships—or at least a few of them—which now go to reward young men for merely passing a good examination, shall be given *without examination* to men who shall have advanced human knowledge in any department. At present, a fellowship of 250*l.* or 300*l.* a year, lasting ten or twelve years, and in some cases for life, may be obtained on showing proof of a good memory—or, at most, a capacity for assimilating other men's ideas. To make discoveries—to follow out a new train of thought, and establish it by experiments specially devised to that end, has been left not only without reward, but almost without recognition, in our two principal seats of learning. Is it to be so always? The world at large, ignorant as it is, has a sounder instinct on this subject, and the man who makes the humblest addition to the stock of knowledge in the world rarely fails to receive the world's respect and honour.

The suggestions I have ventured to make could not, of course, be well carried out unless the Government take into its own hands the appointment to all scientific chairs. Of this I think I see indications. I believe that sooner or later the Government will assume the supreme direction of education in this country. It has already taken primary education under its control, and quite recently, here in Ireland, intermediate education to a great extent. And does the appointment of so many University Commissions not show a disposition on the part of the Government to assume the direction of higher education also?

The following Papers were read:—

1. *Report of Committee on some of the lesser-known Alkaloids.*

See Reports, p. 105.

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2. *Report on the best means of Developing Light from Coal Gas, part I.*

See Reports, p. 108.

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3. *On the Amounts of Sugar contained in the Nectar of various Flowers.* *By* ALEX. S. WILSON, *M.A.*, *B.Sc.*

Nectar, the sweet-tasted liquid found within the cups of insect-fertilised flowers, is of service to the plant possessing it by affording an inducement whereby nsects are attracted to visit the flowers. By this means cross-fertilisation is effected, as bees, butterflies, and other insects, in their search for the nectar, bring with them pollen from other flowers adhering to their bodies which they deposit on the stigmas. Mr. Darwin has shown experimentally what an additional amount of vigour is thus conferred on the resulting seeds in contrast with the degenerating effect of continuous inbreeding or self-fertilisation. Very often this sweet fluid is exuded from special glands, but in other cases from portions of the flower that do not seem to have been specially adapted for this purpose. Morphologically, nectaries may represent very different structures, but not unfrequently they are of

the nature of an aborted organ such as a petal or stamen. It is a disputed point among physiologists whether this saccharine matter is a true secretion or simply an excretion of effete matter from vegetable cells—a bi-product of the chemical changes taking place within these cells. Nectar is, of course, the source whence the bee derives honey, but it also affords sustenance to many different kinds of insects as well as humming-birds. The bright colours of flowers, as shown by Sir John Lubbock's experiments, serve for the guidance of insects to them, and the odours which they emit fulfil the same end. The markings on a flower's petals, too, always converge towards the nectar. The importance of these guides to insects will be apparent from the following estimations, which show how indispensable it is that as little time as possible should be lost by an insect while collecting honey. It must be remembered, also, that in order to protect the nectar from rain, it is usually contained in the least accessible part of the flower. The formation of nectar is observed to take place most freely in hot weather. So great, however, is the economy of the plant, that it is only formed at the time when insects' visits would be beneficial, *i.e.*, when the anthers are shedding their pollen or when the stigma is mature. Biologists believe that the visits of bees, butterflies, and other insects have in past time exercised an important influence in modifying the size, shape, colour, &c., of flowers. The following determinations are of interest as showing to what extent this action goes on, and as a help towards ascertaining the value of this factor:—

SUGAR IN FLOWERS. (Fehling's process.)

	Total	Fruit	Cane? (as fruit)
	mgm.		
1. Fuchsia, per flower	7·59	1·69	5·9
2. Everlasting pea, per flower	9·93	8·33	1·60
3. Vetch (*V. Cracca*), per raceme	3·16	3·15	·01
4. „ per single flower	·158	·158	—
5. Red Clover, per head	7·93	5·95	1·98
6. „ „ floret	·132	·099	·033
7. Monkshood, per flower	6·41	4·63	1·78
8. *Claytonia Alsinoides*, per flower	·413	·175	·283

Approximately, then, 100 heads of clover yield ·8 grm. sugar, or 125 give 1 grm. or 125,000 1 kilo. sugar; and as each head contains about 60 florets, it follows that 7,500,000 distinct flower tubes must be sucked in order to obtain 1 kilogramme of sugar. Now, as honey roughly contains 75 per cent. of sugar, 1 kilo. is equivalent to 5,600,000 flowers in round numbers, or say two and a-half millions of visits for 1 lb. of honey!

Another point worthy of note in these results is the occurrence of what appears to be cane sugar, and that in the case of fuchsia in the proportion of three-fourths of the whole. This is remarkable, as honey is usually supposed to contain no cane sugar, its presence being generally held as certain evidence of adulteration. The question, therefore, arises whether this change, which occurs while the sugar is in the bee's possession be due to the action of juices with which it comes in contact while in the honey-bag, or whether on account of the acid reaction of nectar it may not take place spontaneously.

4. *On the Action of Chlorine upon the Nitroprussides.** *By* Dr. EDMUND W. DAVY, *Professor of Forensic Medicine, Royal College of Surgeons, Ireland.*

The nitroprussides are an interesting class of compounds obtained by the action of nitric acid on the soluble ferro or ferri-cyanides, which were first investigated by

* *In extenso* in the 'Chemical News,' Vol. XXXVIII. No. 105.

Dr. Lyon Playfair several years ago. In this communication the author showed that the statements which exist in the different standard works on chemistry, as to chlorine having no action on those salts, are not correct, at least, as regards several of the nitroprussides, which he has made the subject of investigation; for he has found that some of them are immediately, and others after long exposure to its influence, more or less acted on by that substance, even when they are excluded from light. When, however, they are subjected to the combined action of chlorine and the sun's rays, they are soon completely decomposed, the principal product being an oil-like matter, which appears to possess all the properties belonging to the compound known under the name of chlorocyanic oil ($C_6N_4Cl_{11}$), ferric chloride, hydrochloric acid, and a chloride of the metallic base of the salt employed.

The following nitroprussides, viz., those of potassium, sodium, barium, calcium, zinc, iron and silver, were found to be thus decomposed, when exposed to the combined action of chlorine and sun light, and it is probable that other nitroprussides would be similarly affected.

The only one of those salts, however, which the author has observed resisting this action is that of copper, which has remained apparently unaffected after some weeks' exposure to its influence.

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5. *The Adulteration Act in so far as it relates to the Prosecution of Milk-sellers. By* Ernest H. Cook, *B.Sc., F.R.C.S., Lecturer upon Experimental Physics at the Bristol Trade and Mining School.*

The object of this paper is to call attention to the unsatisfactory state of the law relating to the prosecution of milk-sellers. In many cases innocent vendors have been fined, and also, we may be sure fraudulent dealers have gone unpunished. Notwithstanding that milk-sellers are constantly being fined for selling an inferior article, yet milk continues to be the chief adulterated article of food. The Act has practically failed to deter the sophistication of this article. We can only explain this by the fact that milkmen find that they are fined whether they sell a pure article or an adulterated one. It pays them best to adulterate, and they do so. In proof of this two cases are mentioned. In the first several analysts have certified certain samples of pure milk to be adulterated, and in the second a sample of milk obtained from a cow fed on desiccated grain was certified as skim-milk. The records of our police courts tell us that milk-sellers are constantly being fined for selling milk which they declare most emphatically to be pure and unadulterated. Three courses are open to us to explain these anomalies:—

Firstly. To place implicit reliance on the analyst, and therefore to disbelieve the deliberate statements of the farmers and milk-sellers.

Secondly. To believe the farmer, and therefore to consider the analyst wholly at fault.

Thirdly. To reconcile both by attributing the poverty to a variation in the article.

In most cases the third will be found to be the true explanation.

Notwithstanding the statement of Professor Wanklyn, milk *is* a substance which varies greatly in quality. In the author's experience he has found as great a difference as 18 per cent. in the value of pure milk, and Dr. Voelcker has published analyses in which a much greater difference occurs. It appears that milk is subject to four different kinds of variation, viz.:—

α. A variation owing to the food.

β. A variation owing to the season.

γ. A variation owing to the animal.

δ. A variation owing to health.

Illustrations of these are given in the paper. In consequence of these variations, analysts, if they wish to determine if a sample of milk is adulterated, take, as a standard, the lowest percentage of solids or "solids not fat" which pure milk has been found to contain. This is the principle of the course adopted, but it is open to the following objections:—

Firstly. Each analyst being allowed to fix this percentage himself, we have different standards employed, and consequently may have a milkman fined in one town for selling an article which a neighbouring analyst may declare pure.

Secondly. The percentage fixed upon cannot be the lowest contained by pure milk, because we do not know it. The amount found by Dr. Voelcker (9·3 of solids) is the lowest at present known, but a lower number may be found.

Thirdly. This lower limit is so low that with an ordinary sample a considerable amount of watering may take place without the possibility of detection.

For many obvious reasons it is necessary to remedy this state of things. One method only appears to offer a chance of success, briefly, this is to buy and sell milk by *quality* instead of by *quantity*. The difficulty of introducing this practice is more imaginary than real. One easy method is as follows:—Divide the milk into two qualities, first quality and second quality. The former will include all milk containing 12·0 per cent. of solids or 9·0 per cent. of " solids not fat" or more, and may be sold, say, at 4*d*. per quart. The latter will include all milk containing less than these numbers, and may be sold at 3½*d*. per quart. If a sample of first quality milk be sold which, on analysis, does not contain the stated quantity, the vendor will be fined. The great difficulty here is in making the division into two qualities. In order to do this effectually, some simple instrument capable of making a rough analysis is required. At present such an instrument does not exist, but we may rely on one being forthcoming if the need be felt.

In conclusion, the following advantages are claimed for this method:—

1. The analyst not being called upon to decide upon the purity of the article, but simply whether it contains a certain percentage of solids or of " solids not fat," cannot make such deplorable mistakes as at present.

2. The vendor will not be fined unjustly.

3. It will tend to stop adulteration because a better price can be obtained for a better article.

4. An article of greater constancy will be supplied to the public.

6. *On some Fluor Compounds of Vanadium. By* Professor H. E. Roscoe, *Ph.D., F.R.S.*

FRIDAY, AUGUST 16, 1878.

The following Papers were read:—

1. *Notes on Aluminium Alcohols.* By DR. GLADSTONE *and* ALFRED TRIBE.

In 1876 the authors described the joint action of aluminium and iodine on alcohol, and two aluminium ethylates which resulted from it. They now showed that a similar reaction takes place with methylic alcohol, especially when the aluminium is rendered more powerful by conjunction with deposited platinum; and that an analogous aluminium compound is still more readily formed from amylic alcohol. These two substitution products had not yet been prepared in a pure condition, but the authors had succeeded in preparing the butylic compound in a satisfactory manner. This aluminic butylate is a solid body at the ordinary temperature, but melts when heated, and is capable of distillation. It is very soluble in anhydrous ether or benzole, from which it separates on evaporation, but without crystallising. It is decomposed by water, butylic alcohol and alumina being produced. Its composition was found to be $Al_2(C_4H_9O)_6$. There is also evidence of an intermediate compound, soluble in water, which is probably homologous with the aluminic iodo-ethylate, $Al_2I_3(C_2H_5O)_3$.

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2. *On the Estimation of Mineral Oil or Paraffin Wax when mixed with other Oils or Fats.** By WILLIAM THOMSON, *F.R.S.E.*

Mixed oils are now often used for lubricating purposes, and a common mixture composed of mineral oil with some animal, vegetable, or fish oil is extensively used, and it is an important point to be able by analysis to determine the amount of mineral oil which such mixtures contain; and as I could find no published process to effect this, I devised, after much work, the following, which I found by repeated tests to give accurate results:—Some of the sample is boiled with an alcoholic solution of caustic soda, which converts all the animal, vegetable, or fish oils into soap. This is then mixed with sand, evaporated to dryness on the steam bath, the residue placed in a bottle and washed with petroleum spirit, which has been previously distilled at a temperature not exceeding 190° Fahr. This dissolves out the mineral oil, leaving the soap insoluble. The spirit is now distilled off from the spirit solution in a large flask, and after thus evaporating off the bulk of the spirit, the concentrated solution is transferred to a smaller flask with a hole blown in its side, into which is fitted a cork carrying a thermometer and a glass tube; the thermometer should touch the liquid, going nearly to the bottom of the flask, which is placed on a sand bath and heated at a temperature not exceeding 220° Fahr., and dry air blown into the flask through the tube in the cork, to remove the last trace of spirit, and the residue of mineral oil weighed and calculated on the weight of original mixed oil taken. A small correction must be allowed for an amount of unsaponifiable oil which so-called saponifiable oils always contain, but this is about 0·6 per cent. of the saponifiable oil found.

* 'Chemical News,' Vol. XXXVIII., No. 984, Oct. 4, 1878.

3. *On the Action of Heat on the Selenate of Ammonium.** By Dr. Edmund W. Davy, *Professor of Forensic Medicine, Royal College of Surgeons, Ireland.*

The author read on behalf of his colleague Dr. Charles A. Cameron and himself a paper containing the results of some observations which they had conjointly made on the action of heat upon the selenate of ammonium. The study of the effects of that agent on the sulphate of ammonium, having in the hands of different chemists led to interesting results, the authors thought it desirable to institute some experiments on the selenate of that base, to ascertain whether any corresponding products would be obtained by its exposure to heat, selenic and sulphuric acids agreeing so closely in their properties, and this subject being hitherto uninvestigated as far as they were aware.

Some selenate of ammonium, after thorough drying at 100° C., was heated in a bath of paraffine, the degrees of temperature to which it was exposed being indicated by a thermometer. It was found that when the salt was heated to about 180° C., the evolution of a minute quantity of ammonia could be readily detected, and finding that the amount evolved increased with the rise of temperature, the heat was gradually raised to about 250° C., when the development of ammonia became much more abundant, whilst at the same time water and selenium began to be separated.

This temperature was then continued as long as ammonia was evolved, and till acid vapours made their appearance, when the heat was withdrawn.

On examining the residue after this treatment, it was found that the selenate of ammonium had been completely decomposed, selenium and selenious anhydride, being the remaining products. Wishing to ascertain if any gaseous matter was evolved during the decomposition, some selenate of ammonium was heated in a tube filled with mercury, when a considerable volume of a gas not absorbed by water was obtained, which on examination was found to be nitrogen. It should also be stated, that the salt was observed to have acquired a strong acid reaction, before its final breaking up at the highest temperature to which it had been exposed in the paraffine bath; indicating the formation of an acid salt in the first stage of its decomposition by heat. From the results of those and of other experiments made by the authors, they have come to the conclusion, that when selenate of ammonium is heated it first resolves itself into ammonia and an acid selenate of ammonium, and that this salt, on further heating, breaks up into selenium, selenious anhydride, water, and nitrogen, and that the reactions which occur in the process may probably be expressed by the following formulæ:

1st stage.—$4[(NH_4)_2SeO_4] = 4(NH_4 . H . SeO_4) + 4NH_3$.

2nd stage.—$4(NH_4 . H . SeO_4) = Se + 3SeO_2 + 10(H_2O) + N_4$.

A number of circumstances, however, have as yet prevented the authors being able to confirm the correctness of the above formulæ by actual results.

In conclusion, the foregoing observations are interesting, as they show that in the first stage of the decomposition of the selenate of ammonium by heat, there is an acid salt formed, like as in the case of the sulphate of that base when similarly treated, as was pointed out by Dr. Schweitzer; but in the separation of selenium, in the second stage of the process, there is no analogy in the case of the sulphate of ammonium.

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4. *A New Method of Alkalimetry. By* Louis Siebold, *F.C.S.*

The method recommended by the author consists in the reverse application of Liebig's process for estimating hydrocyanic acid, and is based on the fact that the volumetric determination of an alkaline cyanide by means of silver nitrate is in nowise affected by the presence of free hydrocyanic acid. From the volume of silver solution used, the quantity of alkali may be as readily calculated as that of the cyanogen. If the applicability of this process for alkalimetric purposes were con-

* *In extenso* in the 'Chemical News.' Vol. XXXVIII. 133.

fined to the estimation of caustic alkalies, nobody would, in the author's opinion, think of using it in preference to the process commonly used; but he wished to show that it might with great advantage be applied to the determination of alkaline carbonates. From 0·5 to 1 gramme of the potassium or sodium carbonate should be dissolved in about 100 c.c. of distilled water, the solution mixed with an excess of hydrocyanic acid (10 to 20 c.c. of acid of Scheele's strength), and then decinormal solution of silver nitrate added from a burette until a permanent opalescence is produced. The reaction occurs in accordance with the following equation:—

$$K_2CO_3 + 2HCy + AgNO_3 = KAgCy_2 + KNO_3 + CO_2.$$

The first drop used in excess causes a precipitation of silver cyanide. Whereas under ordinary circumstances hydrocyanic acid is incapable of decomposing alkaline carbonates, it effects a complete decomposition in the presence of silver nitrate. The mixture does not require boiling, and the whole operation may be performed within a few minutes.

If after the end of the titration the mixture is boiled, and the addition of decinormal solution of silver nitrate proceeded with, this time using potassium chromate as an indicator, the volume of silver solution required to ensure complete precipitation of the silver cyanide will be exactly equal to that used in the first titration.

$$KAgCy_2 + AgNO_3 = 2AgCy + KNO_3.$$

This second reaction might then, if desired, be used as a check on the determination. In the presence of chloride, the volume of silver solution used in the second experiment will be greater than that used in the first, the difference between the two being exactly that required to precipitate the chloride. In this manner a determination of the chloride might be readily combined with that of the alkaline carbonate.

The following results were quoted to show the great accuracy of the process:—

Pure Potassium carbonate used	Carbonate found
0·5850	0·5851
0·1670	0·1672
0·8775	0·877[illegible]

Mixtures of pure potassium carbonate and sodium chloride:—

	Used	Found
K_2CO_3	0·2000	0·2005
NaCe	0·0680	0·0683
K_2CO_3	0·9750	0·9750
NaCe	0·1825	0·1830

The author gives the following reasons why for the essay of samples of potash or soda he considers this process as better than the one usually employed:—

1. The solution does not require boiling, and the operation therefore requires less time than the usual process.

2. The change from absolute clearness to an unmistakable turbidity as produced by a single drop of the reagent is more striking than that of the colour of litmus brought about by a drop of normal sulphuric or hydrochloric acid.

3. The test solution being a deci-normal one, the results obtained are more accurate than those obtained with standard normal mineral acids.

4. With but little additional trouble, and without having to operate on fresh sample, the process may be readily coupled with an accurate determination of the chloride present in the alkaline carbonate.

In concluding, Mr. Siebold stated that he was at present engaged in experiments showing a still wider range of useful applicability of this process; and that the results of these experiments he hoped to be able shortly to lay before the Chemical Society.

SATURDAY, AUGUST 17, 1878.

MONDAY, AUGUST 19, 1878.

The following Papers were read:—

1. *Notes on Water from the Severn Tunnel Springs.* *By* WILLIAM LANT CARPENTER, *B.A., B.Sc., F.C.S.*

The plans for the construction of this tunnel had been fully described to Section G, t the Bristol (1875) Meeting, by its engineer, Mr. Charles Richardson. By the ummer of the present year, the trial heading, part of which was to form the per- nanent drain of the tunnel, had been driven more than half way across under the evern, which was 2¼ miles wide at that point, and had successfully passed under he remarkable channel of the "Shoots." In driving through the pennant rock, everal springs had been met with, some of which had since run dry. In the pinion of the engineer, no Severn water could find its way to these springs, the ource of which he thought were the "backs" in the pennant. The author had nalysed water from four springs, and from the Severn at various states of tide, and rom deep land wells in the neighbourhood, the results of which led him to believe hat by far the greater portion of the water flowing from these springs was derived om the Severn. Details of the analyses were given.

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2. *On the Thetines.** *By* E. A. LETTS, *Professor of Chemistry, University College, Bristol.*

The experiments were undertaken as a sequel to the research made by Professor rum Brown and the author on dimethyl thetine and its compounds, and with view to the thorough investigation of the thetines as a group—the phenomena ttending their formation, the action of heat and oxidizing agents on them, and the ifference in their properties as the series is ascended. Incidentally the action of romacetic acid on certain hydrocarbon sulphides, and the action of bromacetic and odacetic ethyl ether on sulphide of methyl were studied.

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3. *On the Spectrum of Chlorochromic Acid.* *By* G. JOHNSTONE STONEY *and* Professor J. EMERSON REYNOLDS.

See above, p. 434.

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4. *Summary of Investigations on the Pyridine Series.* *By* Dr. W. RAMSAY.

These bases, which possess the general formula C^nH_{2n-5}, are tertiary bases. They form an additive product with iodides of alcohol radicals, of which a good example is $C_5H_5N.CH_3I$, best named pyridine methyl-iodide, as it resembles a lt in its constitution. They are not attacked by nitrous acid; and the cyanate, when heated, undergoes no molecular change, but merely splits up into the base, and the usual polymer of cyanic acid, cyanuric acid.

* For a detailed account of the above, see 'Trans. Roy. Soc. Edin.' 1878.

Picoline, C_6H_7N, on oxidation yields a dicarbo-pyridenic acid, $C_7H_5NO_4$, which, on distillation with soda-lime, decomposes into pyridine, C_5H_5N, and carbonic anhydride, $2CO_2$. It has, therefore, the structural formula $C_5H_3N(CO.OH)_2$. Attempts to prepare lutidine, C_7H_9N, from the aldehyde of that acid, as well as by the reaction $C_5H_3N(CO.O.CH_3)_2 - C_7H_9N + 2CO_2$ failed, owing, in the first instance, to the small yield of aldehyde, and, in the second, to the total decomposition of the product into pyridine, carbonic anhydride, and carbon.

In spite of the failure of these attempts, the author regards it as probable that picoline is methyl-pyridine from the following consideration:—The amount of heat evolved in the formation of these bases is probably very high. That heat, added to the amount evolved by the combination of the base with an acid, is likely to be greater than the total number of heat-units evolved during oxidation of the base; hence these bases are unoxidisable in acid solution. But when oxidised in alkaline solution, the amount of heat evolved by oxidation is supplemented by that arising from the combination of the resulting acid with the alkali, and then exceeds the heat evolved during formation of the base. The presence of nitrogen therefore gives great stability to the molecule, and prevents the methyl-groups from being oxidised to carboxyl groups, as is the case with toluol, xylol, &c. At least three acids of the formula $C_7H_5NO_4$ have been discovered, and it is probable that as many as six are capable of existence. These the author has named α, β, and γ, dicarbopyridenic acids. The α-acid is obtained by oxidising picoline or lutidine, and the last two from lutidine.

An attempt to pass from furfurol to pyridine by the series of reactions—

$C_5H_4O_2$,	$C_5H_6O_2$,	C_5H_5OCl,	$C_5H_5ONH_2$,
Furfurol.	Furfuryl alcohol.	Furfuryl chloride.	Furfuryl-amine.

C_5H_5N,
Pyridine,

was unsuccessful, owing to the instability of furfuryl chloride.

From the stability of the pyridine group, and the instability of the furfurol group, the author regards it as probable that the constitution of the former is best expressed by a closed, and that of the latter by an open chain.

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5. *On some of the Derivatives of Furfurol.* *By* Dr. W. Ramsay.

It was found impossible to prepare furfuryl chloride by the action of phosphoric chloride, or of hydrochloric acid gas on furfuryl alcohol, $C_5H_6O_2$, owing to a complete decomposition of the organic matter, with separation of carbon.

Furfurine, prepared by heating furfuramide, and possessing the same formula, $C_{15}H_{12}N_2O_3$, unites with methyl-iodide, forming the hydriodide of methyl-furfurine; this salt, on treatment with ammonia, deposits the base $C_{15}H_{11}(CH_3)N_2O_3$, as a viscous oil, insoluble in water, but soluble in alcohol. The base again unites with methyl-iodide, giving the hydriodide of dimethyl-furfurine, $C_{15}H_{10}(CH_3)_2N_2O_3HI$, also decomposable by ammonia with liberation of the base, dimethyl-furfurine, $C_{15}H_{10}(CH_3)_2N_2O_3$. This base appears also to be capable of union with methyl-iodide.

Furfurine, then, appears to be a secondary base, containing two atoms of hydrogen replaceable by methyl. Whether more can be replaced the author was unable to decide, as the loss by repetition of the operation was very considerable.

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6. *Nitric Acid; its Reproduction from the lower Oxides of Nitrogen.* *By* Bernard C. Molloy.

In treating in this short memoir of the economic use of nitric acid, it would be well to state by way of preface why it is considered worthy of such attention.

We are aware in the first place that it is the highest oxide of nitrogen known, that, parting so easily and freely with its oxygen as it does, it stands highest in the list of oxidising agents, and consequently amongst the most useful chemical re-agents in manufacturing enterprises.

There are two drawbacks in some cases fatal to its use: one is the high price of the acid; and the other the injurious and malodorous gases which are evolved during the deoxidation of the acid. The object, therefore, in these researches has been twofold—firstly, to introduce the greatest possible economy in the use of nitric acid; and secondly, to get rid of the malodorous and injurious gases which are evolved. In effecting the former the latter has been successfully attained.

To make this operation clear it will be well to recall for a moment the severa oxides of nitrogen.

There are five compounds of nitrogen with oxygen, containing respectively 1, 2, 3, 4 and 5 volumes of oxygen to 2 of nitrogen, viz., taking them in the ascending order of the oxygen—

1. Nitrous oxide, N_2O.
2. Nitric oxide, N_2O_2.
3. Nitrous anhydride, N_2O_3.
4. Nitrogen peroxide, N_2O_4.
5. Nitric anhydride, N_2O_5.

If water be added to the fifth or highest oxide, we have nitric acid $H_2N_2O_6$, or $2HNO_3$.

When any oxidisable substance is presented to nitric acid, the nitric acid parts with a portion of its oxygen to combine with the substance to be oxidised, and the nitrogen is evolved, combined with the remaining oxygen as lower oxides of nitrogen.

Under the most favourable conditions not more than fifty per cent. of the oxygen contained in the nitric acid can be used for the purpose of oxidation. In many cases, however, the percentage is as low as twenty. Moreover, a fresh supply of the acid will be required for each successive operation.

Now it will be evident that if sufficient oxygen be made to combine with these lower oxides of nitrogen, nitric anhydride will be formed, which, when combined with water, reproduces nitric acid. To effect this reproduction economically, the "means" employed must themselves be economical in order to be useful.

We will deal with the gases evolved during the deoxidation of nitric acid. These gases will be composed of a mixture of lower oxides of nitrogen, which will be of a deep brownish red colour, caused by the presence of nitrogen peroxide. These gases or fumes are conducted into the chamber or towers where they are to be reoxidised. These towers consist of closed chambers about, for ordinary purposes, thirty feet high and three feet in diameter. Their form and material may be varied, but they may be constructed of glazed earthenware pipes or a slate. The tower rests in a reservoir, into which the reconverted acid falls and from which it is afterwards drawn. Into the sides of the tower may be fitted sight-holes glazed with glass, so that the quantity of the gases may be roughly judged by the depth of the colour inside the tower. The top of each tower is of a conical form, and in the centre of the cone is fixed a jet, through which steam and hot water are forced. This jet is so arranged as to be capable of being easily and accurately adjusted in order to cause a cloud or spray of very finely divided hot water of about a temperature of 100° C. to fall slowly through the tower or chamber. Atmospheric air is allowed at the same time to enter the tower. The construction of the jets should be so arranged as that the quantities of hot water and the admission of air may be regulated at will. As is obvious, the tower should be gas tight, except as hereafter described. Now the gases or fumes coming from the vessel in which the nitric acid is being used will gradually rise till the tower is charged. When so charged the jet is brought into action; steam and hot water are turned on into the jet in such proportions as that the steam will strike and divide the water into a minutely divided spray, the steam itself being condensed in the water, so that a misty spray of hot water slowly falls down through the tower.

In its descent the particles of hot water come into contact with the oxides of

nitrogen. The nitrous anhydride (N_2O_3) and nitric oxide (N_2O_2) are under these conditions immediately oxidised by the air (admitted and drawn in through the air holes or through the jet) into peroxide of nitrogen N_2O_4. The several reactions may be combined thus:—

$$N_2O_3 + N_2O_2 - 3O = 2N_2O_4.$$

This peroxide of nitrogen (N_2O_4) is quickly absorbed by the spray and decomposed by it into nitric oxide and nitric acid. The nitric acid is dissolved by the hot water of the spray and carried down into the reservoir at the foot of the tower. The nitric oxide remains undissolved by the spray, but is oxidised as fast as produced by the air into peroxide, which in turn becomes split up into nitric oxide and nitric acid, the latter being collected as before in the reservoir. The re-action may be approximately shown thus:—

$$6N_2O_4 + 2H_2O = 3N_2O_2 + 8HNO_3.$$

Eventually, therefore, the lower oxides of nitrogen becoming oxidised by contact with air into the higher peroxide, and this in turn becoming absorbed by the spray and divided into nitric oxide and nitric acid, which latter is always dissolved and carried down, and the reactions being successively continuous, the whole of the original nitric acid, when used and operated upon under these conditions, will be regained.

Practically the whole of these reactions occur simultaneously, so that the nitric acid is reproduced from the lower oxides as soon as they are generated.

This process places another weapon in the power of the manufacturer, and renders available for many purposes a re-agent at present limited in its application.

In conclusion, I will only add that in no single instance has the process failed or even varied in its results.

7. *On some Substances obtained from the Root of the Strawberry. By* Dr. T. L. Phipson, *F.C.S.*

The author has found in the root of the strawberry certain substances closely allied with some that are contained in the cinchona barks. The principal of these is called Fragarine, and can be obtained in large quantities by a process which with cinchona bark yields the product called *Cinchona red.* There exists in the strawberry root a kind of tannin, closely allied to quinotannic acid, and when its solution is boiled for some time with hydrochloric acid, it decomposes into glucose and fragarine, which is precipitated as a reddish brown amorphous substance, highly electrical by friction, taking a reddish purple colour with alkalies, yielding nitro- and chloro-compounds of a yellow colour, and a conjugated acid with sulphuric acid. On being heated, fragarine yields water and is decomposed without fusion, yielding much charcoal and a white sublimate, soluble in water, which is, apparently, pyrocatechin; its solution gives a green colour with salts of iron. Melting potash decomposes fragarine with production of dark brown substances and a little protocatechuic acid, which can be isolated by ether from the acidulated solution, and also colours iron salts green.

Whilst fragarine is being produced by boiling with hydrochloric acid there is diffused through the laboratory a very agreeable odour of essence of cedar. The root also yields a product very similar to quinovic acid.

8. *On a new Mineral White Pigment. By* Dr. T. L. Phipson, *F.C.S.*

For many years past attempts have been made by several chemists to discover some new mineral white of a less costly and less dangerous nature than white lead. Very little success seems to have attended these researches until quite lately. First, the oxide of zinc produced by the combustion of the metal in the air was found to have certain properties which allowed it to be used as a non-poisonous substitute for carbonate of lead. But its production is very costly, and its cover-

ing power or "body" is not comparable with the latter. Next, an ingenious white or stone-coloured paint was economically produced from oxide of antimony by Dr. Stenhouse, which appeared to answer very well in certain circumstances. I myself have made a great number of experiments with the view of utilising some of the artificial silicates, such as those of lime, magnesia, and zinc, &c., which possess a very brilliant white colour, by submitting them to a great variety of treatments; but I have been unsuccessful in imparting to them anything like the "body" of white lead; they all become more or less translucid when mixed with oil, like pure silicic acid itself, whatever mechanical treatment they may have previously undergone.

Whilst occupied with these researches I learned accidentally that Mr. Thomas Griffiths, of Liverpool, had obtained a new pigment, the basis of which was the white sulphide of zinc, and on submitting this new product to examination I found, with considerable astonishment, that it surpassed the ordinary white lead in every respect, in colour, in resistance to the weather and gaseous emanations, and in durability; moreover, that it was not destructive to the health of the workmen who manufacture or who use it. Mr. Griffiths has been experimenting, I understand, for about ten years upon the best means of producing this new mineral white upon a large scale, and has, apparently, now brought its preparation to a state of perfection which has gone beyond the most sanguine expectations.

A salt of zinc, which may be the sulphate or the chloride, is precipitated by a soluble sulphide; the latter being either sodium, calcium, or barium sulphide, or a mixture of them; precautions are taken to avoid the precipitation of any black sulphide of iron, if perchance the zinc solutions contain a little of that metal; the bulky product is collected, dried, and transferred to a furnace, where it is calcined for some time at a cherry red heat. During the calcination it is carefully stirred to bring each portion successively in contact with the air; it is then raked out whilst quite hot into vats of cold water, where it is levigated, and afterwards collected and dried.

The result is a white pigment of exquisite beauty. Its covering power, when mixed with oil, is greater than that of any substance hitherto discovered, being about 25 per cent. higher than that of the same weight of pure carbonate of lead.

According to my analysis, this new product is really an oxy-sulphide of zinc, the composition of which varies somewhat according to the length of the calcination and the heat attained. Hence it is a difficult matter to get it exactly of the same composition at each successive operation. Nevertheless, this is attained quite closely enough for practical purposes. The best product appears to correspond in composition as nearly as possible to the formula, $5ZnS + ZnO$. But occasionally a larger quantity of oxide is produced and the product by means improved thereby.

In some experiments which I made for the purpose of testing the capabilities of this new white pigment, as compared with the old zinc white (oxide of zinc), and white lead (pure carbonate of lead), I was perfectly surprised at the results, my own experiments made with the view of discovering a substitute for the latter having proved such utter failures, and I look upon this new oxy-sulphide of zinc pigment as one of the most interesting products hitherto derived from mineral chemistry. As it possesses much more covering power than the old zinc white, or oxide of zinc, it is considerably more economical than the latter. As to white lead, it has only one recommendation as a colour, namely, its great "body" or covering power; but it is liable after a time to saponify the oil, producing a soap which is more or less translucid; moreover, it is darkened by gaseous emanations and it is detrimental to health. The new product possesses none of these drawbacks. It has all the covering power of white lead, combined with permanency in colour, and resistance to the saponifying influence of the oil, and is a much finer white. Nothing more is requisite but to ensure for it a constant composition, and I have little doubt that this difficulty will be overcome in the course of a short time.

TUESDAY, AUGUST 20, 1878.

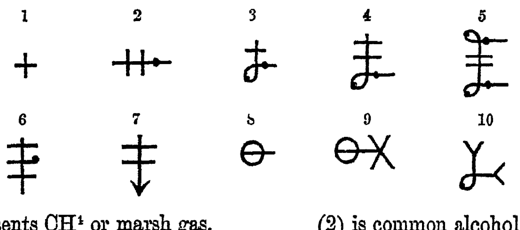
The following Papers were read :—

1. *On a Simplification of Graphic Formulæ.* *By* OLIVER J. LODGE, *D.Sc.*

In the graphic formulæ of a compound the elements are ordinarily represented by their chemical symbols (capital letters), and the connection between the atoms by straight lines joining the letters. Now graphic formulæ are of most use in organic chemistry, where the principal compounds consist only of the elements C, H, O, and N, whose atomicities are generally 4, 1, 2, and 3 or 5 respectively. In any formulæ, therefore, four bonds generally radiate from the letter C; N is the meeting-place of three or five bonds, according to circumstances; two bonds meet at each O, and a single bond terminates at every H. Supposing then that the letters were omitted and the bonds joined together, the position of the atoms would still be apparent as the meeting-place of a definite number of bonds, and therefore the letters are unnecessary.

The simplification proposed in the paper is the omission of the usual symbols used to denote the atoms, and the joining of the bonds in such a way as clearly to define the atomicities, and therefore the natures of the several atoms. Formulæ so drawn become reduced to a sort of geometrical diagram; and conversely any geometrical diagram represents some real or imaginary chemical compound.

For instance, in the accompanying figure—



(1) represents CH^4 or marsh gas. (2) is common alcohol.
(3) is acetic acid. (4) propionic acid.
(5) Succinic acid (without the 2 bars in the middle it would be oxalic, with only one malonic, acid), and so on.

The free bonds of unsatisfied radicals are easily indicated by arrowheads.

When chlorine or iodine substitution compounds are to be shown, the free ends may be dotted, to indicate that the monad is not hydrogen, *e.g.*, Secondary propyl iodide, No. (6). In all cases where graphic formulæ are used, the common empirical formulæ will or should be written alongside; and the element intended by the dot in any particular case will therefore be clear. Other details and numerous illustrations are given in the paper. The constitution of a body is thus exhibited in a very compact form which appeals to the eye and impresses itself readily on the memory. The formulæ of even complex bodies are very rapidly drawn, for a few strokes, instead of representing but a single atom, as H, represents a whole group; for instance (7) is the radical ethyl; (8) is prussic acid; (9) ammonic cyanide; (10) is urea; and the commonly occurring radicals are recognised at once without taking the formulæ to pieces. At the same time the symbols denoting the different radicals are such as arise naturally, and are not arbitrary and intrinsically meaningless such as even *Et* must be held to be; and they may always be analysed whenever required.

2. *On the Detection by means of the Microphone of Sounds which accompany the Diffusion of Gases through a thin Septum.* *By* W. Chandler Roberts, *F.R.S.*

The author pointed out that the passage of a gas through a porous septum was undoubtedly due to molecular motion, and as any facts which bear on molecular movement are of much importance, he exhibited and described various forms of apparatus, by the aid of which the passage of hydrogen through thin septa of paper and graphite might be studied with the microphone. He indicated the several points which appeared to be in favour, as well as those which were against the view that the vibrations of the molecules of the gas could actually be detected, and he stated that further experiments were in progress.

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3. *A short Account of Baeyer's Synthesis of Indigo.* *By* Professor J. Emerson Reynolds, *M.A., F.C.S.*

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4. Dr. Ramsay *exhibited Victor Meyer's Apparatus for taking Vapour Densities of Substances with High Boiling Points.*

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5. *On the Condensation of the Gases hitherto called Permanent.* *By* Professor James Dewar, *F.R.S.*

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6. *On a Method of Elementary Organic Analysis by a Moist Process.* *By* Professor Wanklyn *and* W. J. Cooper.

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7. *On some Peculiarities of the Vartry Water, and on the Action of that Water upon Boiler Plates.* *By* Charles R. C. Tichborne, *LL.D., Ph.D., F.C.S.*

The water of the river Vartry, from which we get our supply in Dublin, has been repeatedly analysed, therefore I will not trouble the section with a detail of its composition. It will be sufficient for my purpose to remind the section of its general composition, which may be stated to consist of—

Organic matter of a peaty nature,	1·6 to 2 grains per gallon.
Mineral matter	$2\frac{1}{2}$ grains per gallon.

The mineral matter chiefly consisting of chlorides of the alkalies, and the alkaline earths in equal proportions.

The hardness is nearly all permanent, as there is but a trace of carbonates present. The point I wish to draw attention to, however, is the presence of nitrates and nitrites. The first are always present, the latter occasionally in the summer and autumn months. They were present when last tried on the 3rd of August. I have never seen any published analysis which mentions the existence of these acidulous radicals. As my object is to determine the condition of the nitrogen salts, and as heat seems to reduce nitrates when occurring in this water, I had resource to evaporation by the aid of a vacuum and sulphuric acid; the test I used being the brucia test, an extremely delicate one if properly applied. For my nitrates I used a thin starch solution, made with a little dilute glycerine to keep it, and a solution of tartaric acid preserved by a little salicylic acid. The iodide of

potassium being carefully purified from iodate, the solutions keep very well, and are reliable. The iodide should be dissolved as required. The Vartry water does not give indications with the tests as a rule without concentrating it. I subjoin the results of my experiments on the 3rd of August:—

1. Water evaporated to $\frac{1}{3}$ at 100° C. gave a very striking indication of nitrites, besides nitrates.

2. Evaporated in a vacuum to $\frac{1}{3}$ it gave no indication.

3. Evaporated *in vacuo* to $\frac{1}{4}$ it gave an indication of nitrites and nitrates.

In January 1878, the Vartry gave no indication of nitrites, but contained, as usual, nitrates, and gave an indication on evaporating to one-half. We see by these observations that evaporation tends to reduce the nitrates. Also that from fermentative action changes occur at certain periods of the year, which result in the reduction of nitrates to nitrites.

We see also that these nitrates and nitrites are present in very minute quantities. I have never found 0·1 of a grain per gallon said to be present in Loch Katrine water; the highest amount I have ever found being 0·06, determined by the aluminium process. But still, when these salts are rapidly concentrated, as they are in the feeding of high-pressure steam boilers, the nitrogen salts become very serious items of corrosion, owing to the ease with which the acidulous radicals are dissociated at high temperature, *e.g.*—

$$NaNO_3 = NaNO_2 + O.$$
$$2NaNO_2 + H_2O = 2(NaHO) + 2NO.$$
$$2NO + Fe = FeO + N_2O.$$

I exhibit a boiler plate, which is not eaten away by the corrosive action of water, but the corrosion is determined by the steam of the Vartry water. I also exhibit glass corrosion produced by the same means.

Some experiments were instituted in sealed tubes which bear strikingly upon this subject, and which I now beg to place before the section.

No. 1.—In this experiment distilled water was boiled in a tube and a piece of bright wire inserted. The tube was then sealed, after the air had been exhausted. It is now some months old, and it will be observed that there is comparatively no action. We are to infer, therefore, from this experiment, that at ordinary temperatures water is without the slightest action upon iron in vacuo. We all know how rapidly iron is oxidized in the presence of water containing air.

No. 2 is iron sealed up in vacuo with Vartry water, and submitted to high-pressure steam at 30lbs. to the square inch. The action is sharp and well marked, the results being the production of ferric oxide in considerable quantities, and magnetic oxide. The latter can be recognised on applying a magnet outside the tube.

The third tube was a similar experiment with pure water, containing 0·1 grain per gallon of nitrate of potassium. This also was sealed in vacuo. The results are almost identical with the second experiment, only that more magnetic oxide seems to have been formed. The fourth experiment was one in which a nitrite was substituted for the nitrate. Here nothing but ferric oxide was formed of a peculiar bright colour, and in scales.

That the corrosion of the boiler plate mainly proceeds from the nitrogenous molecules, I think there can be little doubt. But the quantity of these acidulous radicals being very small, any of the alkaline preservations would remedy this corrosive action. If, however, neglected, these nitrogenous acidulous radicals would almost certainly lead to mischief, and therefore they are imminent sources of danger.

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8. *On a New Process of Photo-Chemical Printing in Metallic Platinum.* *By* W. Willis, *jun.*

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION.—John Evans, D.C.L., F.R.S., F.S.A., F.G.S.

THURSDAY, AUGUST 15, 1878.

Mr. JOHN EVANS gave the following Address:—

IN opening the proceedings of this section, I cannot but call attention to the fact that the present is the third occasion on which the British Association has met in this city, its first meeting here having taken place in the year 1835, or forty-three years ago. On that occasion, as indeed for many years afterwards, the two distinct, though to some extent cognate branches of study, Geology and Geography, were classed in the same section, and its president was a man of whom Irish science may well be proud, and who, I am thankful to say, is still living to enjoy his well-deserved honours—the veteran geologist, Sir Richard John Griffith, the author of the first Geological Map of Ireland. It seems hardly credible that the construction of this map was commenced in the summer of 1812, or sixty-six years ago; but the records of the Geological Society of London testify to the more remarkable fact that Sir Richard Griffith was elected a fellow of that society in 1808—seventy years ago. Indeed, in 1854, when the Wollaston medal was awarded to the then Dr. Griffith, the president, the late Professor Edward Forbes, spoke as he said reverentially to one of the earliest members of the society, and to a geologist who appeared in print before he, the president, was born. It was well said on that occasion that the map lately mentioned was one of the most remarkable geological maps ever produced by a single geologist; and I make no doubt that those who are at present engaged on the Geological Survey of this island will testify, as did their predecessors, to the value of this "surprising monument of observation and skill."

When speaking of the Geological Survey of Ireland, it will not, I am sure, be thought out of place if I offer here a tribute of respect to the memory of one who was originally a student in the college within whose walls we are assembled, and who subsequently occupied posts of the highest importance in connection with the Geological Society of Dublin and the Geological Survey of Ireland, besides filling the professorial Chair of Geology in this University: I mean Dr. Thomas Oldham, the late director of the Geological Survey of India. With the marvellous amount of work which he was enabled to accomplish in that country you are all acquainted, and you will all share in the regret that the period of his well-earned retirement—that "requies optimorum meritorum"—should have been so quickly cut short by death. His name will, however, long survive, and future students of geology will have no difficulty in recognising the distinguished labourer in their science after whom the Cambrian *Oldhamia* of the Wicklow hills so worthily received its name.

But to return to this Association.

On the next occasion of its meeting in Dublin, in 1857, Section C. had become devoted to geology alone, and geography was excluded, the president being Lord Talbot de Malahide, a nobleman whom also we still have among us, and who is alike well known to archæologists and geologists.

As the last meeting of the Association in this city took place twenty-one years ago, it would at first sight appear that in opening our proceedings I might with propriety dwell on the progress which has been made within that period in the development of the geology of Ireland. I must, however, remind you that it is only four years since the Association held its meeting in what I may almost call the neighbouring town of Belfast, when the accomplished chief of the Geological Survey in Ireland presided over this section, and delivered an address in which some of the more interesting features of the country, especially those of the volcanic district of the north-east of this island, were discussed. During the present year, moreover, he has published his comprehensive work on the Physical Geology and Geography of Ireland, which I commend to you as far more likely to call your attention to the characteristic features of the country and the latest discoveries with regard to its geology than anything I could compile.

In addition to this, there has appeared during the present year another interesting volume, which records the impressions of a highly intelligent foreign geologist on visiting this country. I mean the 'Aus Irland' of Dr. Arnold von Lasaulx, Professor of Mineralogy in the University of Breslau. For this volume, in which shrewd remarks on the country and its inhabitants are mingled with geological observations and valuable comparisons of the Irish formations with those of other countries, we are indebted to the meeting of the British Association having been held two years ago at Glasgow, which attracted the author to visit the British Islands.

So much having lately been published upon the geology of this country, I shall content myself with making a very few general observations with regard to it, and propose subsequently to touch briefly on some of those questions which, within the last twelve months, have occupied the attention of those who are engaged in the advancement of our science.

As to the geology of this country, I may observe that we are here assembled just on the edge of that great central plain which forms so important a feature in the map of Ireland, and which stretches from Dublin Bay on the east coast to Galway Bay on the west, with hardly a portion of it attaining to an elevation of three hundred feet above the sea, over a tract of country nearly one hundred and fifty miles in extent in almost every direction.

The boundaries of this great plain and those of the Carboniferous Limestone almost coincide, so that we have here the somewhat remarkable feature of a formation which in England is of such a character as to have received the name of the Mountain Limestone, constituting in the neighbouring island nearly the whole of the plain country. In some of the north-western counties, however, as for instance Fermanagh and Sligo, it assumes its more mountainous character. Nearly the whole of this central plain is overlain with boulder clay, limestone gravel or middle drift, and extensive bogs, so that the subjacent rock is but occasionally seen. In several places detached bosses of Old Red Sandstone rise through the limestone, and there is also good reason for believing, with Professor Hull, that the whole of the area was at one time covered with the upper members of the carboniferous group, including the true coal measures, of which unfortunately but small patches remain, and those upon the margin of the plain. From the absence of the upper Palæozoic, Mesozoic, and Cainozoic formations over the area, Professor Hull has arrived at the conclusion that the surface remained in the condition of dry land, while that of England was being submerged beneath the waters of the sea, over the bed of which nearly all these formations were deposited. To a certain extent, however, he leaves it an open question whether some of the Mesozoic strata which occur over the north-east of Ireland may not have been deposited over the centre and south. The amount of denudation over this central area has, no doubt, been such that the chances of even Professor Judd finding traces of these latter deposits appear at first sight to be but small; but whether the whole of this vast amount of denudation is due to the wasting influence of rain, rivers and other sub-aerial agents of erosion, is a question which I venture to regard as at all events open to discussion. It appears to be the case that in some parts of the north of Ireland the whole of the upper Carboniferous beds had been denuded before the deposition of

any Permian strata, as these are deposited immediately on the Carboniferous Limestone; and if this amount of denudation had taken place in pre-Permian times in the north, there seems a possibility of the same having been the case in central Ireland. If so, it is possible that some traces of the later deposits may yet be found on the central plain. Certainly, if we are still to regard the white chalk as a deep-sea deposit, the cretaceous rocks of the north-east of Ireland must have at one time extended farther south than they do at present, and somewhere or other there must have been shore deposits of that period formed further south than the Upper Greensand of Antrim. The careful investigations of Professor Judd have largely extended our knowledge of the Secondary rocks of the western coast and islands of Scotland, and he has been able to show that the Jurassic series of the Western Highlands could not have had a thickness of less than three thousand feet. It is therefore hard to believe that with such a development in so closely neighbouring a district, the deposits of the same age in Ireland can have been restricted to their present area.

Professor Judd considers that the amount of denudation in the Scottish Highlands since the Mesozoic and even the Miocene period has been enormous, and that the great surface features of the Highlands were produced in Pliocene times. It seems therefore possible, if not probable, that so long a period of exposure to subaerial influence as that assigned to the central plain of Ireland by Professor Hull, would have resulted in a more uneven land surface than that which we now find. At all events, the history of this remarkable physical feature is one which is of high interest, and can hardly as yet be considered as closed.

With regard to the mountainous districts surrounding the central plain, we shall, I believe, have the opportunity of visiting some parts of the Wicklow Mountains, a district from which a portion, at all events, of the native gold of Ireland was procured in ancient times, as indeed it continues to be. Of the abundance of gold in this country in early times, a glance at the magnificent collection of ancient ornaments preserved in the Museum of the Royal Irish Academy will serve to give an idea. Even in times more recent than those in which the bulk of these ornaments were made, gold was an important product of this country, and I am tempted to quote a few lines from an early English poem, 'The Libell of Englishe Policye,' witten in the year 1436. In treating of the commodities of Ireland, the author says that the country is

"So large, so gode, and so commodious
That to declare is straunge and merveilous.
For of silver and gold there is the ore
Among the wilde Irish, though they be pore;
For they ar rude and can theron no skille
So that, if we hadde ther pese and good wille,
To mine and fine and metal for to pure
In wilde Irishe mighte we find the cure;
As in Londone saith a jewellere
Which broughte from thennes gold oor to us here,
Wherof was fined metal gode and clene,
That at the touch no better coude be sene."

Sir William Wilde has observed that the south-western half of Ireland has yielded a greater amount of gold antiquities than the north-eastern, and probably this would hold good with regard to the production of the metal itself, though it has been found in the counties of Antrim, Tyrone, and Derry, as well as in those of Dublin, Wicklow, Wexford, and Kildare.

The north-east of Ireland possesses, however, another geological feature peculiar to itself in that great expanse of volcanic beds which formed the subject of Professor Hull's address to this section at the Belfast meeting. My only object in now mentioning them is again to call attention to their containing the only remains of a Miocene flora which are to be found in this island. Analogous beds were detected in the corresponding basalts in the Island of Mull by the Duke of Argyll in 1851. With the exception of the Hempstead beds of the Isle of Wight,

which should probably be classed as Oligocene, and the Bovey Tracey beds of Devonshire, these are almost the only deposits of Miocene age in the British Isles. The contrast presented by the scarcity of deposits of this period in Britain with their abundance in the north-west, centre, and south of France, Switzerland, and generally in the south of Europe, is striking. Instead of thick deposits covering hundreds of square miles of country, like the Miocene beds bordering the Pyrenees or those of the great system of the Auvergne, we have small patches owing their preservation either to volcanic outbursts having covered them up, or to some favourable circumstance having preserved them from total denudation. Whether we are to assume, with the late Professor Edward Forbes, that the general dearth of these strata in the British Isles arose from the extent of dry land which prevailed during the long interval between the Eocene and Pliocene periods, or whether we assume the former existence of widespread marine deposits which have since been entirely removed, the case is one not without difficulty. At all events, the absence of representatives of this period within the British area has a tendency to prevent a due appreciation of the enormous extent of the Miocene period being generally felt in this country. Nor, generally speaking, do we, I think, take a fair estimate of the remoteness in time to which we must date back the commencement of that lengthened period. Professor Haughton, judging from the maximum observed thickness of each successive deposit, has calculated that a greater interval of time now separates us from the Miocene period than that which was occupied in producing all the Secondary and Tertiary strata from the Triassic to the Miocene epoch, and, without endorsing the whole of my accomplished friend's conclusions, I incline to concur in such an estimate. When it is considered that the Ballypalidy beds of Antrim and the Lough Neagh clays are the sole representatives in Ireland of two periods of such length and importance as the Miocene and Pliocene, their high interest will be more apparent, and I trust that no opportunity of minutely studying them will be neglected.

There is one other point with regard to Irish geology on which it will be well to say a few words, though it is of a negative rather than a positive character. I mean the absence, so far as at present known, of Palæolithic implements in this country. It is true that Professor Hull, in the book to which I am so much indebted, speaks of a raised beach on the Antrim coast as containing worked flints of that rude form and finish known as Palæolithic; but this is a slip of the pen, by which the author has fallen into the not uncommon error of applying a term which is merely significant of the age of the implements to their external character. However rude may be the workmanship of the flint implements found at Kilroot, they belong to the Neolithic, and not to the Palæolithic period. So far as I am aware no example of any implement belonging to the age of the mammoth, rhinoceros, and other members of the post-pliocene fauna has as yet been found in Ireland. Indeed, the remains of *Elephas primigenius* and its associates are of exceedingly rare occurrence in this country, though they have been found with those of bear and reindeer in the Shandon Cave near Dungarvan. It is, of course, impossible to foretell what future researches may bring to light; but judging from analogy it seems hardly probable that until ancient river-gravels containing the remains of the post-pliocene group of mammals are found in this island, veritable Palæolithic instruments will be discovered. The association of the two classes of remains is so constant that we may fairly assume that the animals formed the principal food of the Palæolithic hunters, and that any causes which lead to the absence of the one class will lead to the absence of the other also.

There is, however, one member of that old quaternary group which is far more abundant in Ireland than it is in England or on the continent of Europe—the *megaceros*—which has rightly received the appellation of *Hibernicus*.

I hope that we may have an opportunity, under the guidance of Mr. Richard Moss, of seeing some of the remains of this "antlered monarch of the waste" in the position in which they were originally interred, and it will be an interesting question for consideration whether these remains can be regarded as of the same geological age as those of the English caves and river-gravels, or whether they do not for the most part belong to what Professor Boyd Dawkins has termed the Pre-

historic period. It seems by no means improbable that this gigantic stag survived in this country for ages after he had become extinct in other lands, and that the view held by Professor Hull of his extinction being due to persecution by man is correct. If this be so it would seem to follow that the human occupation of Ireland is of far more recent date than that of the sister country.

And this brings me to one of those questions which have of late been occupying the attention of geologists. I mean the date which is to be assigned to the implement-bearing beds of Palæolithic age in England. Dr. James Geikie has held that for the most part they belong to an interglacial episode towards the close of the Glacial period, and regards it as certain that no Palæolithic bed can be shown to belong to a more recent date than the mild era that preceded the last great submergence.

His follower, Mr. Skertchly, records the finding of Palæolithic implements in no less than three interglacial beds, each underlying boulder clays of different ages and somewhat different characters—the Hessle, the purple, and the chalky boulder clay. This raises two main questions, first, as to how far Dr. Croll's theory of the great alternations of climate during the Glacial period can be safely maintained; and secondly, how far the observations as to the discovery of implements in the so-called Brandon beds underlying the chalky boulder clay can be substantiated. Another question is how far the Palæolithic deposits can be divided into those of modern and ancient valleys, separated from each other by the purple boulder clay, and the later of the two older than the Hessle beds. It would be out of place here to discuss these questions at length. I will only observe, that in a considerable number of cases the gravels containing the implements can be distinctly shown to be of much later date than the chalky boulder clay, and that if the implements occur in successive beds in the same district, each separated from the other by an enormous lapse of time, during which the whole country was buried beneath incredibly large masses of invading ice, and the whole mammalian fauna was driven away, it is a very remarkable circumstance. It is not the less remarkable because this succession of different Palæolithic ages seems to be observable in one small district only, and there is as close a resemblance between the instruments of the presumedly different ages as there is between those of admittedly the same date. I have always maintained the probability of evidence being found of the existence of Man at an earlier period than that of the post-glacial or quaternary river gravels, but, as in all other cases, it appears to me desirable that the evidence brought forward should be thoroughly sifted and all probability of misapprehension removed before it is finally accepted. In the present state of our knowledge, I do not feel confident that the evidence as to these three successive Palæolithic deposits has arrived at this satisfactory stage. At the same time it must be borne in mind that if we make the Palæolithic period to embrace not only the river gravels but the cave deposits of which the south of France furnishes such typical examples, its duration must have been of vast extent.

In connection with the question of Glacial and Interglacial periods, I may mention that of climatal changes in general, which has formed another subject to which much attention has of late been given. The return of the Arctic Expedition, and the reports of the geological observations made during its progress, which have been published by Captain Fielden, one of the naturalists to the Expedition, in conjunction with Mr. De Rance and Professor Heer, have conferred additional interest on the question of possible changes in the position of the poles of the earth, and on other kindred speculations. Near Discovery Harbour, about latitude 81° 40′, Miocene beds were found containing a flora somewhat differing from that which was already known to exist within the Arctic regions. "The Grinnell Land lignite," say the authors of the report, "indicates a thick peat moss, with probably a small lake, with water lilies on the surface of the water, and reeds on the edges, with birches, poplars, and taxodiums on the banks, and with pines, firs, spruce, elms, and hazel-bushes on the neighbouring hills." When we consider that all of the genera here represented have their present limits at least from twelve to fifteen degrees farther south, while the taxodium is now confined to Mexico and the south of the United States, such a sylvan landscape as that

described seems entirely out of place in a district within six hundred miles of the pole, to which indeed, if land then extended so far, these Arctic forests must have also extended in Miocene times. Making all allowance for the possibility of the habits of such plants being so changed that they could subsist without sunlight during six months of a winter of even longer duration, I cannot see how so high a temperature as that which appears necessary, especially for the evergreen varieties, could have been maintained, assuming that Grinnell Land was then as close to the North Pole as it is at the present day. Nor is this difficulty decreased when we look back to formations earlier than the Miocene, for the flora of the secondary and Palæozoic rocks of the Arctic regions is identical in character with that of the same rocks when occurring twenty or thirty degrees farther south, while the corals, encrinites, and cephalopods of the carboniferous limestone are such as, from all analogy, might be supposed to indicate a warm climate.

The general opinion of physicists as to the possibility of a change in the position of the earth's axis has recently undergone modifications somewhat analogous in character to those which, in the opinion of some geologists, the position of the axis has itself undergone. Instead of a fixed dogma as to the impossibility of change, we find a divergence of mathematical opinion and variations of the pole differing in extent, allowed by different mathematicians who have of late gone into the question, as for instance the Rev. J. F. Twisden,* Mr. George Darwin,† Professor Haughton,‡ the Rev. E. Hill,§ and Sir William Thomson.‖ All agree in the theoretical possibility of a change in the geographical position of the earth's axis of rotation being affected by a redistribution of matter on the surface, but they do not appear to be all in accord as to the extent of such changes. Mr. Twisden, for instance, arrives at the conclusion that the elevation of a belt twenty degrees in width, such as that which I suggested in my presidential address to the Geological Society in 1876, would displace the axis by about ten miles only; while Professor Haughton maintains that the elevation of two such continents as Europe and Asia would displace it by about sixty-nine miles; and Sir W. Thomson has not only admitted, but asserted as highly probable, that the poles may have been in ancient times "very far from their present geographical position, and may have gradually shifted through ten, twenty, thirty, forty, or more degrees without at any time any perceptible sudden disturbance of either land or water."

I am glad to think that this question, to which I to some extent assisted to direct attention, has been so fully discussed, but I can hardly regard its discussion as being now finally closed. It appears to me doubtful whether eventually it will be found possible to concede to this globe that amount of solidity and rigidity which at present it is held to possess, and which to my mind at all events seems to be in entire disaccordance with many geological phenomena. Yet this, as the Rev. O. Fisher ¶ has remarked, is pre-upposed in all the numerical calculations which have been made. I am also doubtful whether, in the calculations which have been made, sufficient regard has been shown to the fact that a great part of the exterior of our spheroidal globe consists of fluid which, though of course connected with the more solid part of the globe by gravity, is readily capable of readjusting itself upon its surface, and may, to a great extent, be left out of the account in considering what changes might arise from the disturbance of the equilibrium of the irregular spherical or spheroidal body which it partially covers. It appears to me also possible that some disturbances of equilibrium may take place in a mysterious manner by the redistribution of matter or otherwise in the interior of the globe. Captain F. J. Evans,** arguing from the changes now going on in terrestrial magnetism, has suggested the possibility of some secular changes being due to internal, and not to external causes; and if it be really true that there is a difference between the longest and shortest equatorial radii of the earth, amounting to six thousand three hundred and seventy-eight feet,†† such a fact would appear

* Quart. Jour. Geol. Soc., 1878, p. 35.
† Proc. R. S., vol. xxv. p. 328. Phil. Trans., clxvii. p. 271.
‡ Proc. R. S., 1877, 1878.
§ 'Geol. Mag.,' June, 1878.
‖ Rep. Brit. Assoc., 1876, p. 11.
¶ 'Geol. Mag.,' July, 1878.
** *Nature*, May 16, 1878.
†† Thomson and Tait, Phil. p. 648.

to point to a great want of homogeneity in the interior of our planet, and might suggest a possible cause for some disturbance of equilibrium.

I have mentioned Professor Haughton among those who, from mathematical considerations, have arrived at the conclusion that a geographical change in the position of the axis of rotation of the earth is not only possible but probable. In a recent paper, however, he has maintained that, notwithstanding this possibility or probability, we can demonstrate that the pole has not sensibly changed its position during geological periods. He arrives at this conclusion by pointing out that in the Parry Islands, Alaska and Spitzbergen, there are Triassic and Jurassic deposits of much the same tropical character, and then by a geometrical method fixing the north pole somewhere near Pekin, and the south pole in Patagonia, within seven hundred miles of a spot where Jurassic ammonites occur, shows that such a theory is untenable. In the same way he fixes the pole in Miocene times near Yakutsk, within eight hundred miles of certain Miocene coal beds of the Japanese islands. These objections are at first sight startling, but I think it will be found that if, instead of drawing great circles through certain points, we regard those points as merely isolated localities in a belt of considerable width, there is no need of fixing the pole of either the Jurassic or the Miocene period with that amount of nicety with which Professor Haughton has ascertained its position. The belt may indeed be made to contain the very places on which the objection is founded. Still the method is a good one, and I hope that as our knowledge of foreign geology extends it may be still further pursued. There is, however, one farther consideration to be urged, and that is as to the safety of regarding all deposits of one geological period as contemporaneous in time. Although an almost identical flora may be discovered in two widely-separated beds, it appears to me that chronologically they are more probably of different ages than absolutely contemporaneous; and, inasmuch as the duration of the Miocene period must have been enormous, there would be time—if once we assume a wandering of the poles—for such wandering to have been considerable between the beginning and end of the period.

I must not, however, detain you longer upon this phase of geological speculation, but will advert to a subject of more practical interest, the discovery of Palæozoic rocks under London. So long ago as 1856 the Kentish Town boring had shown that immediately below the Gault red and variegated sandstones and clays occurred, which Professor Prestwich regarded as probably of Old Red or Devonian age. The boring of Messrs. Meux and Co. has now shown that under Tottenham Court Road, at a depth of little more than nine hundred feet from the surface, there are true Devonian beds, with characteristic fossils, and that Mr. Godwin-Austen's prophecy of the existence of Palæozoic rocks at an accessible depth under London has proved true. Professor Prestwich, from a consideration of the French and Belgian coal-fields, inclines to the belief that in the district north of London carboniferous strata may be found. Unfortunately the expense of conducting deep borings, even with the admirable appliances of the Diamond Boring Company, is so great that I almost despair of another experimental bore-hole like that carried out in the Wealden district under the auspices of Mr. Willett, being undertaken.

In the department of theoretical geology I would call your attention to some experiments by M. Daubrée, of which he has given accounts at different times to the French Academy of Sciences. In these experiments he has attempted to reproduce on a small scale various geological phenomena, such as faulting, cleavage, jointing, and the elevation of mountain chains. Although the analogy between work in the laboratory and that on the grand scale of nature may not in all cases be perfect, yet these experiments are in the highest degree instructive, and reflect no little credit on the ingenuity of the distinguished chief of the Ecole des Mines.

With regard to recent progress in palæontology, I must venture to refer you to Professor Alleyne Nicholson's inaugural address lately delivered to the Edinburgh Geological Society, but I cannot pass over in silence the magnificent discoveries in North America, which are principally due to the researches of Professors Marsh, Leidy, and Cope. The *diceratherium*, a rhinoceros with two horns placed trans-

versely, and the *dinoceras*, somewhat allied to the elephant, but with six horns, arranged in pairs, are as marvellous as some of the beasts seen by Sir John Maundevile on his travels, or heard of by Pliny. But perhaps the most remarkable series of remains ever discovered are those which so completely link the existing horse with the *eohippus* and *orohippus*, and still farther extend the pedigree of the genus *equus*, which had already been some years ago so ably traced by Professor Huxley.

Of these American discoveries, as well as those made in the Tertiary beds of Europe, M. Albert Gaudry has largely availed himself in his recent beautiful volume on the links in the animal world in geological times, a work which will long be a text-book on the inter-relation of different orders, genera, and species. I am tempted to make use of some portions of M. Gaudry's own analysis of the book, which he communicated to the Geological Society of France. Beginning with the marsupials of the close of the Secondary and beginning of the Tertiary period, he shows that they are succeeded by such animals as the *pterodon*, the *hyænodon*, the *proviverra*, and *arctocyon*, which present a mixture of marsupial and placental characters, and to some extent justify a theory of the transition from one order to the other. He next examines the marine mammalia, and points out that, so far as at present known, they make their appearance later than those of the land, and that the examination of the pelvis of the *halitherium* tends to support the idea of the mammals, such as the sirenians, which at the present day have no hind limbs, being descended from terrestrial quadrupeds, for those limbs in the *halitherium* are much less reduced than in its recent successors, the dugong and manatee. After tracing the numerous links which are to be found between the extinct and living pachydermata, he proceeds to show that, notwithstanding the great distance between them and the ruminants, transitions may be seen. The earliest ruminants were devoid of horns and antlers, but possessed upper incisors, and by a comparison of the molars of different genera it may readily be conceived how the large bosses of the omnivorous teeth of the pachyderms gradually shaded into the small crescents of the teeth of the ruminants. At the same time the passage from the heavy and complicated extremities of the limbs of the pachyderms to the simpler and lighter feet of the ruminants can be traced. The history of the horse family is also discussed, and the descent of existing proboscidians from the mastodonts is shown to be probable, though the previous forms from which the mastodonts and dinotheria are derived are as yet unknown. Nor can the origin of the carnivora as yet be suggested, though passages between the six existing families of the order may be observed. In conclusion, M. Gaudry devotes a chapter to the quadrumana, and thinks that palæontological observations tend to diminish the isolation in which these mammals now stand with regard to the other orders.

One of the most important features insisted on by M. Gaudry is that to which I have already alluded—the development of the complicated molars of most mammals. His view is that by a comparison with early and with fœtal forms the probability may be shown of these compound teeth being made up of what in earlier forms were simple teeth—or, as he has termed them, denticules—which have coalesced in the same manner as have some other parts of the normal bony skeleton. In the compound teeth the denticules in some cases preserve their original conical form, as in the pig tribe; in others are elongated transversely, so as by their junction to form ridges, as in the tapirs; while in others, again, they are drawn out into longitudinal crescents, as in the ruminants. Between these forms there are, of course, innumerable transitions. They do not, however, appear to me to affect the importance of M. Gaudry's observations, which must be regarded as of the highest value in all attempts to trace the inter-relation of different forms of mammalian life. I must not, however, detain you longer on this subject, as I trust that I have said enough to show the importance and interest of this book.

The discoveries of early forms of birds with teeth do not come within M. Gaudry's province; but Professor Marsh has largely added to our knowledge of these remarkable forms. The Tertiary *Odontopteryx toliapicus* from Sheppey, described by Professor Owen, seems rather to be endowed with bony tooth-like processes in the jaw, than with actual teeth, and the head of the *Argillornis* from

the same locality is at present unknown. But the *Hesperornis* and *Ichthyornis* from the cretaceous beds of America possess veritable teeth, in the one case set in a long groove in the jaw, and in the other in actual sockets. Such intermediate, or, as Professor Huxley would term them, intercalary forms, tend materially to bridge over the gap which at first sight appears to exist between reptiles and birds, but which to many palæontologists was far from being impassable, long before the discoveries just mentioned. The amphicœlous character of the vertebræ of *ichthyornis* presents another most remarkable peculiarity, which is also of high significance. I hear rumours of the discovery of another *archæopteryx* in the Solenhofen Slates, which is said to present the head in a much more complete condition than that in which it occurs on the magnificent slab now in the British Museum. As yet, I believe, the jaws have not had the matrix removed from them; but should they prove to be armed with teeth, it will to me be a cause of satisfaction rather than surprise, as confirming an opinion which some fifteen years ago* I ventured to express, that this remarkable creature may have been endowed with teeth, either in lieu of or combined with a beak.

I must not, however, detain you longer with any of these general remarks, which are, moreover, becoming somewhat egotistic, but will now proceed to the business of this Section, in which I hope that more than one paper of great value and interest will be forthcoming.

The following Papers were read:—

1. *Sketch of the Geology of the Environs of Dublin. By* Professor E. Hull, *F.R.S.*

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2. *On the Ancient Volcanic District of Slieve Gullion. By* Joseph Nolan, *M.R.I.A., &c., of H.M. Geological Survey of Ireland.*

Slieve Gullion is a somewhat isolated mountain situated some few miles north of Dundalk, and west of the picturesque hilly country lying between the bays of Dundalk and Carlingford. The rocks which mainly compose it are massive dolerites and elvanites, which have been erupted through granite of Lower Silurian age. From evidence obtained in a neighbouring locality, there is every reason to believe that the period of this eruption was about the close of the Palæozoic epoch. On the west and south of the mountain the elvanite forms a remarkable dyke-like ridge, when it changes in its character from a granitoid rock to a felstone porphyry. Simultaneously with this change, suggesting conditions of less intense heat and pressure, a remarkable fragmental rock makes its appearance. It is here almost altogether composed of granite pieces; so much so that it might be taken for a disintegrating condition of that rock, but that the base is not crystalline. Its mechanical character is confirmed on tracing the ridge further, where the granite gives place to Silurian slates and grits. Here there is a mixture of slate and granite fragments, and still further in the slate district it is almost altogether composed of slate *débris*. At all these places the fragmental rock is intimately associated with the porphyry, so that where both are well exposed in sections it is impossible to draw any line of demarcation between them, the lower part of the former gradually acquiring the character of the latter, by the appearance in increasing quantity of fragments of porphyry, until it ultimately passes into that rock.

That we have here something analogous to volcanic agglomerate we can scarcely entertain a doubt. Nevertheless, it differs very much from the usual type of that rock, as it is, except in the deepest portions, mainly composed of pieces of non-volcanic rocks, those pieces being of the crust through which the igneous mass was protruded, and varying accordingly; granite agglomerate prevailing in those portions formerly occupied by that rock, a mixture of slate and granite near the boundary of these formations, and slate fragments almost exclusively in the Silurian country to the south-east. It is impossible to account for these phenomena by supposing

* Nat. Hist. Rev., vol. v. p. 421.

that we have here the result of an ordinary eruption, where lava is ejected, and we are forced to believe that it was altogether aeriform. From the great extent of country over which the agglomerate occurs, it is not improbable that the explosion which accompanied the protrusion of the nearly horizontal dyke affected a considerable area at the same time, disrupting and triturating to powder the overlying rocks, the vast volume of which, falling back into the opening, together with the rapid consolidation of the igneous mass consequent upon so great a disengagement of the interstitial vapour, combined to check the volcanic activity before it could produce scoriæ or lava.

Another point of interest in connection with this district is the evidence it affords of the connection between the plutonic and the volcanic rocks. This is not indeed as fully exemplified here as in other districts, as, for instance, in the Western Isles of Scotland, where Professor Judd traces all the gradations from granite to pumice and scoriæ, yet it is sufficiently illustrative of the principle when we find plutonic rocks graduating into others which by their protrusion have produced mechanical accompaniments.

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3. *Notes on the Glaciation of Ireland, and the Tradition of Lough Lurgan. By* W. Mattieu Williams, *F.R.A.S., F.C.S.**

In comparing the vestiges of ancient glaciation (especially those of Norway and Ireland) with the deposits of existing Alpine glaciers, the author has been much impressed with the very general fact that, although the "till" and other varieties of boulder clay are of unquestionable glacial origin, they are unrepresented by the moraines, &c., of the glaciers now existing in the temperate zones; and on the other hand true representatives of recent Alpine moraines are very rarely found among the ancient glacial deposits.

An explanation of this is offered. Living Alpine glaciers (with a few exceptions) terminate on mountain slopes, and are sources of mountain torrents. These torrents wash out, carry away, and afterwards deposit as a distinct alluvium the material corresponding to the clayey matrix of the ancient drift, leaving behind only the boulders and smaller stony particles to form the stony heaps of modern moraines.

The remarkable absence of such moraines on the very long and remarkably glaciated coast line and mountain slopes of Scandinavia is explained by the fact that the glaciers of that region originated in a great *nevé*, covering the table-land fjelds which overflowed down their boundary valleys into the sea.

The great central plain of Ireland is compared to such a fjeld. During the glacial epoch it was covered with ice, was a great *nevé* or glacier source, and its outlet glaciers flowed on all sides over the surrounding mountain barriers down their seaward slopes into the ocean and terminated there, leaving the bulk of their mineral burdens in the sea.

Glaciers thus outthrust upon the waters under a climate in which the annual snowfall exceeded the annual thaw, would be thinned from below and grow from above, and thus extrude their mineral matter downwards instead of upwards, as in Alpine temperate-zone glaciers.

They would present a further inversion of such glaciers, by bending upwards by flotation as they advanced, instead of downwards by gravitation; and their crevasses would therefore be formed at the lower instead of the upper surface of the ice, and would gape downwards instead of upwards.

As they became thawed below by the friction of their advance they would accumulate a vast amount of *débris* at their base, effecting far more erosion than the clearer ice-bottom of modern Alpine glaciers. Thus, more fine slimy impalpable powder or clay material would be formed, and this, in its slimy condition

* The views of the constitution of ancient glaciers, and the formation of boulder clay, contained in this communication, are more fully discussed in a paper on 'The Great Ice Age and the Origin of the Till,' published in the 'Quarterly Journal of Science' of April, 1877.

would be thrust forward so long as the glacier exerted considerable pressure by its gravitation. But as it thinned out, this pressure must have gradually diminished until it became *nil*, when the depth of water and thinning of the ice effected approximate flotation. Then the mud, &c., would be deposited, and the shallowed sea would form a submarine plain of the neutral depth over which the glacier would just lightly slide and thus form a striated pavement of till.

If the conditions remained constant, this deposit would continue level as we see it at Bodö and other places in Norway; but if climatic or other conditions fluctuated, the varying advance and recession of the glacier and its varying pressure would produce a ploughing up of the soft material into submarine ridges such as abound in the Irish bays that are mouths of the great glaciated valleys, and are also found so abundantly on and near the coast.

The islands of Clew Bay are specified as striking examples of this.

Having lately met with an account of a tradition which describes a great fresh-water lake on the present site of Galway Bay, and having already noted many of these long ridges of till in that Bay, the author revisited Galway with the object of further examining them in reference to the tradition which states that the fresh-water lake was converted into a bay by the sea breaking through the boundary or bar that had previously separated the fresh from the salt water.

The general result of this exploration of both shores of the Bay and several of its islands was, that the existence of such a barrier or of a series of such barriers appears very probable; but their position does not indicate so large a lake, as the traditionary Lough Lurgan which is described as one of the three great lakes of Ireland.

The outermost barrier probably stretched from the cliffs of Barna (which are formed by the sea washing away one of these ridges of till and exposing a fine perpendicular section about 50 feet thick) to Aghinish Point, meeting the Kilcrogan promontory on the way, when this ridge of drift extended much farther westward, as its present truncated headland of till indicates that it must have done.

These, and other minor headlands of till, all the obvious remains of promontories that have been cut off, are connected by a bar that stretches obliquely and irregularly across the Bay from Barna, in County Galway, to Finvarra Point, in County Clare.

The promontories and island ridges do not extend fairly across the Bay, but lie in a direction from E.N.E. to W.S.W. They are still so numerous and extensive as to visually overlap each other and present the appearance of an inner bar, enclosing the inner bays of Galway and Kinvarra. This occurs when they are viewed from the shore of Salthill, about 2 miles from Galway.

A minor bar is well seen from the railway on leaving Oranmore station on the way to Galway. The till cliff of Roscarn Point is there seen opposed to a similar cliff on the opposite side with a channel cut between them.

If the ancient barrier was nearly as high as the present cliffs of Barna, the waters of the traditionary lake must have backed over a large area of the flat land around Galway, and it may even have been continuous with Lough Corrib.

Another form of drift which covers a large area of the central limestone plain of Ireland is described as analogous to that which covers the Dovrefjeld, the Fillefjeld, and most of the other Norwegian fjelds, and which the author has described in detail in 'Through Norway with Ladies,' pages 50 and 238, as the material which subsided when the great *nevé* of the Great Ice Age finally thawed away. It is neither boulder clay nor loose stony moraine material, but an intermediate agglomeration of sand and gravel with boulders that are more angular than those of moraines or boulder clay, and show little or no signs of striation. The name of *boulder sand* or *glacier gravel* is suggested. It occurs, commonly as a thin layer spreading over the limestone and occasionally as long humpy ridges, and is connected with the formation of Eskers.

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4. *Notice of some additional Labyrinthodont Amphibia and Fish from the Coal of Jarrow Colliery, near Castlecomer, County of Kilkenny, Ireland. By* William Hellier Baily, *F.L.S., F.G.S., M.R.I.A., &c., Acting Palæontologist to the Geological Survey of Ireland.*

The Geological Survey having recently acquired a number of specimens from Jarrow Colliery, near Castlecomer, through the kindness of Mr. J. Dobbs, the proprietor, and Mr. A. McLuckie, manager of the colliery, consisting of amphibian reptiles and fish, in addition to those previously collected from the same colliery, at the request of Mr. Hull, Director of the Survey. The following short description of these interesting specimens was given by Mr. Baily.

This series of fossils consists of more than 50 specimens, all belonging to the vertebrata, 25 of them being amphibia, 20 fish, and the remainder of doubtful character.

The largest amphibian is one already described by me as *Anthracosaurus Edgei* in a paper read before the Royal Irish Academy, January 13, 1873. These remains indicate an animal which must have been from eight to ten feet in length; they consist of a triangular-shaped head, under jaw, and other portions of the skull, not however in a good condition for study, together with a group of twelve well-defined vertebræ and ribs in much better preservation than those before obtained.

The other amphibian remains I have identified with the following genera and species, described by Professor Huxley in the 'Transactions of the Royal Irish Academy, vol. xxiv. (Science), pp. 351, &c.:—

Keraterpeton Galvani, of which there are four specimens.

Ophiderpeton Brownriggii, two specimens.

Dolichosoma Emersoni, three specimens.

Erpetocephalus rugosus, one specimen.

There are others evidently amphibian, including two heads, which I have not yet succeeded in identifying; possibly some of them may belong to one or both of the two genera alluded to by Professor Huxley, but not figured, under the names of *Dichospondylus* and *Brachyscelis*.

The fish remains include a fine example of what I believe to be *Megalichthys Hibberti*. This great sauroid is here represented by a specimen three feet seven inches in length, the extremity of the tail being deficient.

Another fine fish, referred to the genus *Cœlacanthus*, appears to be allied to *C. granulatus Agassiz*, hitherto confined to Permian strata, only the caudal extremity having previously been known. The skeleton of this fish is very complete, its length being 22 inches, and breadth at commencement of ventral fin six inches.

In this collection there are also some groups of ribs and other bones, which correspond with those of a large fish from the same colliery, named *Campylopleuron* by Professor Huxley, but which may possibly be identical with the fish we have referred to *Megalichthys Hibberti*.

Several specimens of the defence spines of cestraciont fish, *Gyracanthus formosus*, Ag.,* and a single palatal tooth of *Ctenodus*, complete the list of fish which have been identified. There are also several detached bones and fragments in this collection of vertebrate remains at present undetermined.

* *G. formosus* and *G. tuberculatus* I believe to be identical, as suggested by Agassiz.

FRIDAY, AUGUST 16, 1878.

The following Papers were read:—

1. *On the Exploration of Kent's Cave. Fourteenth Report.* See Reports, p. 124.

2. *Sixth Report on the Victoria Cave Settle.*—See Reports, p. 377.

3. *Report on Fermanagh Caves.*—See Reports, p. 183.

4. *Fourth Report of Commission on Underground Waters.* See Reports, p. 382.

5. *The Relative Ages of the Raised Beaches and Submerged Forests of Torbay. By* W. PENGELLY, *F.R.S., F.G.S., &c.*

Near Hope's Nose and Berry Head, the northern and southern horns of Torbay, Devonshire, there are fine examples of a raised beach about 30 feet above the level of the existing tidal strand; whilst along the central shores of the bay, at Tor Abbey, Paignton, Godrington, and Broad Sands, there are exposed at low water, more or less frequently, considerable accumulations of clay, with stumps of trees rising vertically, and having roots and rootlets ramifying through the mass. In short, Torbay presents admirable studies of the raised beaches and submerged forests found so frequently at intervals along the entire coasts of Devon and Cornwall, and affords evidence, so far at least as the bay is concerned, that during the formation of the beach the country was about 30 feet lower than at present, whilst at the time of the forest growth it was not less, but may have been much more, than 80 feet higher than now; and that, in each case, the movement was so uniform and so tranquil as not to destroy or to modify the approximate horizontality of the areas. It has always been admitted that the beaches and the forests cannot have been coeval; and there has been a prevalent but not an unchallenged *belief* that the beaches are the older. The object of this paper is to afford *proof*, through evidence hitherto overlooked, of the correctness of this chronology.

The parish of Paignton, forming the central shore of the bay, is terminated on the north-east by a narrow gulley, through which a rivulet reaches the sea. At this point the sea cliff is no more than 20 feet high; as it extends towards the south-west it gradually reaches 55 feet, and thence, with a gentle declivity, it descends to within a foot or two of the sea-level, at about ·25 mile from the rivulet. Beyond this, the coast for a considerable distance is a sandy plain, covered with greensward a very few feet above high-water level. The cliff just mentioned consists of two zones; the lowermost being the well-known Trias of South-Eastern Devon, whilst the uppermost belongs to a much more recent formation.

A study of the upper zone shows that the materials are remarkably angular, and consist of fragments of grit derived from *Devonian* beds at no great distance; that they are very loosely aggregated, have no approach to a stratified arrangement, but lie with their longest axes at all angles to the plane of the horizon; that the accumulation—never more than a few feet thick—is thinnest where the cliff is highest: that the contour of the surface on which it lies is very much the same as that of the present surface; and that stones so prevalently angular and so lacking in arrangement could never have been subjected to the rolling and assorting power of the sea; in other words, that the accumulation is of *sub-aërial* origin. When, however, the Torbay raised beaches were formed, and the country was 30 feet lower than at present, the greater part of the Paignton cliff was *submarine*; hence the bed of angular stones must have been lodged in its present place at a period subsequent to the *elevation* of the beaches.

On following the coast towards the sandy plain on the south-west, the bed of angular stones passes under a bed of clay. This superposition, distinct and unmistakeable, is exposed for a distance of nearly 400 feet; and the clay, occupied with stumps and roots of large trees, is finally covered with a thick accumulation of peat, traceable, especially after violent gales, in all directions, and to the low-water line; forming, in short, a well-marked remnant of the Torbay Submerged Forest. The clear superposition proves, beyond a doubt, that the period of the forest growth was subsequent to that of the formation of the bed of angular stones, which, as already shown, was in its turn subsequent to the era of the elevation of the beaches. The facts show, moreover, that since the beach era the Torbay district has never been at so low a level as it was at that time.

6. *Experiments on Filtration of Sea Water through Triassic Sandstone.** *By* ISAAC ROBERTS, *F.G.S.*

7. *On the New Geological Map of India. By* V. BALL, *M.A., F.G.S.*

The last occasion when the subject of the geology of India was prominently brought before this Association was during the meeting at Dundee in 1867, when the late lamented Dr. Oldham described the general features and sequence of formations as then known. To his memory a just tribute has already been paid by the President of the Section and Professor Hull. Of him, on the occasion of his leaving India, it was well said by the present Superintendent of the Survey, Mr. H. B. Medlicott, F.R.S., "Where he has sown others have reaped."

Since the year just alluded to considerable progress has been made, and the map now exhibited shows the state of our knowledge up to a twelvemonth ago, when it was sent to press. From its small scale of 64 miles to the inch it is but little more than an index, and merely indicates the limits of the principal formations. For large tracts of India, however, maps, showing the minor details and subdivisions already exist.

Some idea of the magnitude of India may be gathered from the fact that a portion of country equal to Ireland, big as it looks on the map opposite on the scale of one inch to a mile, would make but an inconsiderable gap were it removed from the map of India.

This map is intended to illustrate a *manual* of the geology of India, which is now being prepared by the two senior members of the Survey, Messrs. Medlicott and Blanford. The publication of this work, which will take place towards the end of the present year, will, it is expected, place Indian geology on a more stable and externally intelligible footing than it has hitherto enjoyed. In Europe it is hoped to prove the means of enlisting the interest and critical aid of geologists in elucidating many of the peculiarly perplexing questions connected with the subject

* Incorporated in the Report on 'Underground Waters.' See Reports, p. 397.

of homotaxis. In India it is hoped that the work will incite local amateurs to aid our small staff. In former times much good yeoman's service was done by amateurs, whose observations were incorporated in Greenough's well-known map. But in the India of to-day it would be difficult to name half a dozen amateur geologists. The causes of this scarcity of volunteers are not difficult to explain. There is now more pressure from official duties, and the facilities for making short runs to Europe during periods of relaxation are vastly increased.

The details of the geology of India are far too complicated to be disposed of in a speedy review like the present. The more especially as some of our palæontologists have attempted to establish minute correlation of horizons with those recognised and established in Europe. Hence have arisen what are known as "palæontological contradictions"—the marine *faunas*, where existing, not always pointing to the same conclusions as the *floras*.

Broadly speaking, it may be said that there are two geologies in India—that of the Himalayas and adjoining tracts, and that of the Peninsula proper. The former conforms in general characters with that of Europe, but the latter is very much *sui generis*, unlike, at least as regards many of the formations, the geology of any other well-known tract on the earth's surface. It is on this account that a duplicate arrangement of the index has been found to be necessary.

The author then gave a brief description of the principal Peninsular formations, and pointed out their leading characteristics and probable correlation with European rock systems. He indicated on the map the position of the principal coalfields, and stated that the total area of actual coal measures was possibly not less than 30,000 square miles. The position of the coalfields in reference to that of many of the large cities was most unfortunate, and as regards the southern and western parts of India native coal was generally undersold by English and Australian.

Regarding the Talchir boulder bed, he was anxious to retract an early opinion of his which had recently been quoted by the President of the Geological Society of London. The glaciation of some of the boulders since found was as distinct as it was on the boulders exhibited to the meeting by Mr. Williams in connection with his paper on the glaciation of Ireland. And recently, as also on a former occasion some years ago, he had come upon a boulder deposit in the Talchir series, which was full of masses of Vindhyan quartzite which must have been carried for 50 or 60 miles from the nearest possible source, and had in all probability been ice borne.

With some remarks on the nature and distribution of laterite, the author concluded his brief sketch.

SATURDAY, AUGUST 17, 1878.

The following Papers were read:—

1. *On the supposed Radiolarians and Diatoms of the Carboniferous Rocks. By* Professor W. C. WILLIAMSON, *F.R.S.*

At the meeting of the British Association in 1872, Mr. Carruthers described some small objects to which he gave the generic name of *Traquairia*, and which he concluded were Radiolarian skeletons. A characteristic series of these objects having been obtained by the author, he felt compelled to reject Mr. Carruthers' determination as to their nature. They are small spherical bodies, from which project numerous slender and apparently muricated branching prolongations, which have at a superficial glance the appearance of spines, but which were shown to be something very different. The entire sphere is encased in a structureless membrane, of which the supposed spines are tubular, thin-walled, cylindrical extensions, and which in turn give off numerous symmetrically-arranged tubular branches, which probably ramified in a mucilaginous (?) investment. Within this outer membrane were one or two other capsular membranes, the innermost of which was found, in several examples, to be filled with cells that bore every indication of being vegetable tissues, being absolutely undistinguishable from similar cells found in the interiors of macrospores, and of cryptogamic sporocarps found associated with the Traquairiæ. These combined features led the author to regard the germs as belonging to the vegetable rather than to the animal kingdom, and to represent a cryptogamic form of reproductive structure.

The author further described the minute organisms found in some of the mountain limestones of North Wales, and which have been regarded as Radiolarians by some geologists. These appear to be wanting in true Radiolarian characteristics, but most of them seem rather to have been hollow, calcareous spheres. It is the opinion of Professors Roscoe and Schorlemmer that the substitution of carbonate of lime for silica in these organisms is a most improbable occurrence, and one that can only be deemed possible in the case of organisms whose originally siliceous composition is beyond the reach of doubt—which is very far from being the case in the instances referred to.

Some time ago, Count Castracane announced a discovery of numerous remains of marine and fresh-water Diatoms in the siliceous ash remaining after coal had been subjected to certain chemical processes, of which the Count recorded the method. Dr. Roscoe permitted Mr. Smith, one of his able assistants, to make for the author similar preparations of thirty examples of Yorkshire and Lancashire coals, prepared according to Count Castracane's directions, in Dr. Roscoe's laboratory, under the eye of that distinguished chemist. There is every guarantee for the correctness of these preparations, but none of them exhibit the least traces of Diatomaceous structures. Hence the author concludes that, so far as his experience enables him to judge, there are as yet no evidences of the existence of either Radiolarians or Diatoms during the Carboniferous age.

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2. *On some Fossils from the Northampton Sands. By* JOHN EVANS, *D.C.L., F.R.S., &c.*

These fossils from the ironstone beds of Duston, near Northampton, are casts of lithodomous borings originally made in lumps of coral, impressions of which

they still bear on their outer surface. In the interior, the presence of the shells is still to be traced. Their history appears to be that the cavities made by the boring shells were first filled with limonite, subsequently converted into carbonate of iron and eventually into hematite. Last of all, the enclosing coral has been entirely removed by the infiltration of water charged with carbonic acid. This last process has probably taken place since the emergence of the beds from below the sea-level. The Northampton sands have been fully described by Mr. Samuel Sharp, F.G.S., in the 'Quart. Journ. of the Geological Society.'—Vol. xxxiv.

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3. *Notes on some new species of Irish Fossils. By* WILLIAM HELLIER BAILY, *F.L.S., F.G.S., M.R.I.A., &c., Acting Palæontologist to the Geological Survey of Ireland.*

A new species of starfish was described by the author of this paper, under the name of *Palasterina Kinahani*, from Lower Silurian strata of Caradoc-Bala age, rocks on shore near Bannow, county of Wexford; also two new species of Cephalopod shells from Carboniferous limestone, under the following names—

Goniaties Leesoni, townland of Tomdeely South, county of Limerick;

Orthoceras Clarkii, townlands of Doohyle South and Doohybeg, county of Limerick.

MONDAY, AUGUST 19, 1878.

The following Papers were read:—

1. *On the Metamorphic and Intrusive Rocks of Tyrone. By* JOSEPH NOLAN, *M.R.I.A., &c., of H.M. Geological Survey of Ireland.*

The rocks described in this paper occupy the central parts of County Tyrone, extending from Omagh eastwards and north-eastwards towards Slieve Gallion. They consist for the most part of an amorphous green hornblendic rock, in the midst of which is a wide lenticular tract of micaceous gneiss and schist. The author shows that these two classes pass gradually into each other, and that even among the amorphous hornblendic rocks traces of schistose structure can generally be observed, while local transitions into schist frequently occur. Gradations into more crystalline rocks were also noted and described, those of a hornblendic character passing into a felspathic variety in which little or no hornblende occurs, while quartz and orthoclase are developed, so that a coarse quartz porphyry is produced, passing ultimately into granite.

It was also shown that some of the granite was intrusive during the period of the Old Red Sandstone and its association with metamorphic rocks of Lower Silurian age explained on the hypothesis that the intrusive granite was due to re-metamorphism at the later period, so that portions of the already crystalline rocks were completely fused and became irruptive. That metamorphic action in this district continued up to and even after the Old Red Sandstone age seems to have been the opinion of the late General Portlock, who in his 'Geological Report on Londonderry with Parts of Tyrone,' &c., has described these rocks and their relations to each other at considerable length. He did not seem to have considered the granite to be intrusive, but merely a metamorphosed condition of what we now call the Lower Carboniferous Sandstone, which was then classed with the Old Red formation.

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2. *On the Origin of Crystalline Rocks. By* T. STERRY HUNT, *F.R.S.*

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3. *On some New Areas of Pre-Cambrian Rocks in North Wales. By* HENRY HICKS, *M.D., F.G.S.*

In addition to the areas of pre-Cambrian rocks already described by the author, he now includes amongst that ancient group the following, which he has recently explored, accompanied by Professor Torell, of Stockholm, and Mr. Tawney, of Cambridge, and during part of the time by Professor Hughes, of Cambridge, and Dr. Sterry Hunt, of Montreal.

1. Some cupriferous schists with their associated green bands (intrusive greenstone of the Survey), and including Robel Fawn, to the north of Dolgelly.
2. The so-called 'intrusive felspathic porphyries and Greenstone breccias,' in the neighbourhood of Pwllheli.
3. The so-called intrusive syenitic (Rhos Hirwain Syenite) and felsitic masses and the associated schists which together form the extremity of the promontory of Caernarvonshire, and also Bardsey Island.
4. The so-called 'intrusive felspathic porphyries' in the neighbourhood of Llanfihangel and Nevin.

5. The granite and felstone of the Eifel range, and some masses of felstone to the north.

6. The so-called 'altered Cambrian,' to the south of Glyn Clifon.

7. The ridge of granite and the whole of the so-called altered Cambrian rocks in Anglesea.

In these areas it was found that the rocks resolved themselves into three very well-defined groups, and as the author had already recognised that these groups formed part of three distinct formations at St. David's, unconformable on one another, he proposed to divide the rocks of North Wales in the same manner.

The lowest beds are like his *Dimetian* at St. David's, and consist chiefly of granite or granitoid gneiss rocks.

The next in ascending order is the great felsitic group, and for this he proposes the name *Arvonian*,* since it forms so large a part of the mountains in Caernarvonshire.

The third includes most of the so-called altered Cambrian beds, and consists chiefly of schists, or schistose rocks, and is usually a highly chloritic group. This he associates with the *Pebidian* of St. David's.

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4. *On "Cervus Megaceros." By* William Williams.

The "Cervus Megaceros," commonly called the "Irish Elk," whose remains often occur in the marl beds under the peat bogs of Ireland, appears to have been drowned by miring in the stiff clay forming the beds of lakes which were once very numerous in the country, but which have since silted up, and are now occupied by peat bogs. The author, having been engaged for ten weeks making excavations in search of these remains in the Bog of Ballybetagh, ten miles from Dublin, had arrived at the following conclusions—1st, that the animal had lived after the first glacial epoch, as he found the remains resting on the lower boulder clay; 2nd, that the clay in which he found them seemed to indicate a temperate climate, as it was mostly composed of vegetable matter, indicating very little degradation of mineral matter from the surrounding hills; 3rd, the clay last mentioned is covered with a bed three feet thick, containing hardly any vegetable matter, it being almost all mineral. He concludes that this bed of clay was produced by ice action degrading and wearing down the hills. That it is glacial he infers—

1. From its texture, it being ground granite.

2. From its quantity; an ordinary mild climate would not wear down the hills to produce such a bed, and as it is at a level of 800 feet it has not been imported from the drainage of other places.

3. From having found a reindeer's antler in this bed, he infers that a sub-arctic climate must have prevailed at time of its deposit.

4. From the broken state in which the antlers are found, he cannot conceive any force which would have been sufficient to break one of these beams of hard sound bone three inches in diameter, unless the vertical pressure of immense masses of ice, while the antlers were embedded in the lower clay; running water could not do it; for the teeth have not their corners broken off, nor are the tracks of the blood-vessels in the antlers ground off or water worn.

Hence he infers that the animal lived after the deposit of the lower boulder clay, and previous to that of the upper boulder clay, or that it lived inter-glacial and may have been exterminated by the last ice period.

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5. *On the Rocks of Ulster as a Source of Water-Supply. By* William A. Traill, *M.A.I., H.M. Geological Survey of Ireland.*

The author referred to the backward state of the study of hydro-geology in Ireland, and to the acknowledged necessity for larger and purer supplies of water for

* From the Roman name *Arvonia*, and from which the present name of Carnarvon is derived.

many towns in Ulster. In too many cases the present supplies were derived from the uncertain and dangerous sources of shallow-surface wells, situated within the habitable area—sources universally condemned as scarcely possible to be free from pollution.

The two great systems of water supply were contrasted—that by catchment basins with reservoirs, and that by deep wells or borings. The author strongly advocated the latter, where geological formations would warrant a trial. He showed that many towns in England were successfully supplied by artesian wells or borings into the Chalk or New Red Sandstone formations.

The rocks of Ulster were then reviewed with special reference to their suitability for rendering water by boring, and the best localities for such operations enumerated.

Among the formations which did not possess the essential conditions necessary for success were mentioned the Lower Silurian rocks which comprise the greater portion of the counties of Down, Louth, Armagh, and Monaghan, and the granitic tracts of Newry, Slieve Croob and Mourne, in which localities the catchment basin system had to be adopted, as was the case for the Newry water supply.

In the same category were placed the granitic and metamorphic tracts of Donegal and West Londonderry.

The New Red Sandstone—in England one of the chief formations in which to bore for water—occupies in Ulster a very limited surface area, being for the greater part overlaid by other formations. Artesian borings in these rocks had proved successful, as at the "Cromac Springs" in Belfast, while in other cases they had been unsuccessful, from a wrong selection of sites.

The Chalk and Hibernian Greensand formations were shown to be the great water-bearing strata of Ulster, occupying a very extensive area in the counties of Antrim and Londonderry, but overlaid by other formations, such as the Tertiary basalts. The Mesozoic rocks form a geological basin, the basaltic area occupying the centre, with the Chalk and Greensand cropping out almost continuously along its margin, and underlaid by the plastic clays of the Lias or Keuper marls. The occurrence of this basin was clearly demonstrated by the elevations and dip of the chalk around its margin, and its deep-seated existence inside, as at Templepatrick and other places. The presence of large quantities of water in the Cretaceous beds was apparent everywhere, from the number of large springs along the outcrop, and the constant outpouring of water where the lip of the basin was low, resulting in frequent landslips, as at Garron Tower, Carnlough, Glenarm, Whitehead and other places.

The existence of water held under hydrostatic pressure within the basin was also evidenced by the numerous large perennial springs occurring in the basaltic plateau.

The sequence of the formations within this area and the occurrence of water-bearing strata were then enumerated. Below the so-called upper basalt there exists the first great water-bearing stratum at the ferruginous lithomarge bed of the iron-ore measures. For potable purposes it is too highly charged with hydrated oxide of iron. The lower aluminous bed is also water producing, of a purer quality, but less plentiful; the districts where these occur are, however, comparatively small.

By boring through the overlying basalt within this extensive basin the chalk and greensand could readily be pierced—if within the area of the lower basalt, at no great depth—and where, undoubtedly, a plentiful and pure supply of water would be obtained.

The districts where such, with every prospect of success, might be attempted would be approximately along the valley of the river Bann, or near Ballymena, Ballymoney, Coleraine or Antrim. The districts of Cookstown, Dungannon and Moneymore were differently situated geologically, but the formations were favourable, and water had been proved in the bore-holes for iron ore in that neighbourhood.

The author strongly advocated, for certain localities in Ulster, the adoption of deep wells or borings for the purpose of obtaining water supplies.

6. *On the Occurrence of certain Fish Remains in the Coal Measures, and the Evidence they afford of their Fresh-water Origin.** By* JAMES W. DAVIS, *F.G.S., L.S., Hon. Secretary of the Yorkshire Geological and Polytechnic Society.*

A few miles south-west of Leeds, in the district of Morley and Adwalton, there is a bed of cannel coal which is extensively wrought. It occurs about 130 yards above the silkstone or blocking coal; the latter forming the base of the middle coal measures in the West Riding of Yorkshire. An average section of the bed of cannel or stone coal is as follows:—

	Feet	Inches
Impure cannel	0	1
Cannel coal	0	6
Impure cannel	0	2
Dirt	0	2
Common coal	0	3
Slightly impure cannel	0	5
Black shale	0	3

In the cannel coal, and more numerously in the impure cannel above and below it, there occur numerous fossil remains of fish. They consist of both elasmobranchs and ganoids, but by far the most common are specimens of *Cœlacanthus lepturus*, Ag. The extent and seeming method of deposition of the cannel coal—viz., in a series of small inland lakes, at times dried up, and at others more or less filled with water—taken in conjunction with the internal anatomy of the Cœlacanthus and the frequent occurrence of the fossil bones of Labyrinthodonts, lead to the inference that these swampy pools were very similar to those found in Africa and Australia at the present time, where Lepidosiren and Ceratodus inhabit their muddy beds, and during the dry season, when the ponds and streams are dried up, are enabled, by the action of a lung-like air-bladder, to exist either out of the water or buried in the mud until the rainy season again enables the fish to breathe in the ordinary manner by gills. The Cœlacanthus are similarly provided with a swim bladder, whose walls have been erroneously described as osseous, which, so far as can be ascertained, served an exactly similar purpose to that of the Lepidosiren now existing. These facts, together with others cited in the paper, point to the conclusion that the strata were of subaqueous, and in all probability freshwater origin.

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7. *On the Discovery of Marine Shells in the Gannister Beds of Northumberland.† By* G. A. LEBOUR, *F.G.S.*

The author described the circumstances of the find, which took place in the first instance near the village of Whittonstall, in South Northumberland, at the beginning of the present year (1878). He then adverted to some hitherto unrecorded previous observations of marine forms in the Lower Coal Measures in the neighbourhood of Wylam and Prudhoe, by Mr. G. C. Greenwell, F.G.S. The species altogether were the following:—

A, from Whittonstall (four localities):
Aviculopecten papyraceus.
Av. sp., two forms not sufficiently well preserved for specific determination.
Orthoceras sp., a small elegant form.
Encrinite stems, decomposed in every case.

* Published in full in the 'Proceedings of the Yorkshire Geological and Polytechnic Society' for 1878.
† The subject will be found treated more fully in the author's 'Outlines of the Geology of Northumberland.' London and Newcastle, 1878.

B, from Wylam and near Prudhoe:

Goniatites sp. } quoted from memory by Mr. Greenwell.
Microconchus sp. }

Mr. Lebour then described the Gannister beds of the district, discussed their relations to the overlying and underlying members of the Carboniferous series, and concluded that, north of the Tees, the lines defining the division stratigraphically were purely arbitrary.

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8. *Report on proposed Kentish Explorations.*—See Reports, p. 380.

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9. *Report on Fossils of N. W. Highlands of Scotland.*—See Reports, p. 130.

TUESDAY, AUGUST 20, 1878.

The following Papers were read:—

1. *On the Influence of "Strike" on the Physical Features of Ireland. By* EDWARD T. HARDMAN, *F.C.S., F.R.G.S.I., Geological Survey of Ireland.*

Although not often mentioned in geological works, the influence of "strike" in determining the lines of direction of the principal physical features of a country is recognised by most geologists, but in few countries is the relation so distinctly shown as in Ireland. The author was led to pay attention to this subject on reading Mr. J. F. Campbell's paper 'On the Glaciation of Ireland,' * in which that gentleman assumes that the south-west and north-east trend of some of the mountains of Ireland is due to the glacial action of a huge ice sheet passing over Ireland from the south-west of Scotland. After some years' examination, however, the author has found that in most cases the trend of the hills, and course of rivers, &c., are determined by the strike alone; and he now wished to place the facts noted before the section:—

(1) *Mountains.*—The Donegal highlands trend to the south-west, along the line of strike of the ancient crystalline stratified rock. The basaltic plateau of Antrim follows in outline the windings of the outcrop of the underlying chalk, and, consequently, the strike of the basalt upheaved with it. The Mourne Mountains and Slieve Croob also coincide in direction with the stratified rocks on their flanks, except where joints or faults have given rise to minor lateral valleys, *e.g.* Carlingford Lough. Adherence to the line of strike is also seen in the hills forming the flanks of the Wicklow Mountains, in the Kilkenny and Tipperary coal-fields, the Comeragh and Knockmealdown Mountains, and is most remarkably shown in that series of flexured carboniferous, old red sandstone, and Silurian rocks forming the hills of Cork and mountains of Kerry, the axes of which stretch from Dungarvan (Co. Waterford) to Cape Clear and Bantry Bay. Its influence is again shown in the shaping of the high ground forming the Munster coal-field, and finally in the mountainous district of Connemara; although here, in places, obscured by the action of faults. The Twelve Pins, Muilrea, the mountains flanking Killarney harbour, and the country northwards around Nephin Mountain are striking examples. Towards the central plain the isolated mountains of old red sandstone and Silurian rocks rising through the carboniferous limestone, viz., the Slieve Bloom Mountains, the Devil's Bit, and the Galtees, conform to the same rule, the axis in strike and direction being parallel.

(2) *Rivers.*—In the North of Ireland especially, many of the rivers follow the windings of the strike. The Suir follows the line of strike for eighty miles, only beginning to cross it about ten miles from the sea. The Blackwater runs along the strike for seventy miles of its course, crossing it for only sixteen miles. The Lee is directed by the strike for some fifty miles of its length, as is also the Bandon River for the greater part of its course, while the Shannon may be traced along the strike of the beds for by far its greatest distance.

(3) *Inland Lakes.*—Most of the lakes are conformable to the strike in their greater outline, the smaller details being determined by the jointing. Of these may be mentioned Lough Neagh, Loughs Corrib and Mask, Lough Erne (most notably), Lough Allen, Lough Derg, and the far-famed Lakes of Killarney.

(4) *Sea Loughs, Bays, &c.*—The majority of these may be included:—Lough Foyle, Belfast Lough, Strangford Lough, Lough Larne. The most notable examples are those in the south-west:—Roaring Water Bay, Dunmanus Harbour,

* 'Quart. Journ. Geol. Soc.,' London, May 1872.

Bantry Bay, Kenmare River, and Dingle Bay; also the mouth of the Shannon, Galway Bay, and Clew Bay. Further north the principal bays and indentations along the line of coast stretching from Broadhaven to Donegal—Killala Bay, Sligo Bay, and Donegal Bay—have been excavated in their great outlines along lines of strike.

In conclusion, the author pointed out that nature had adopted the least expensive method of working, since it is always easier to excavate along a line of strike than across the bedding. Usually cleavage, or incipient cleavage, is induced along the line of strike by the forces which upheaved the rocks, and denudation is most easily effected therefore in that direction.

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2. *On Hullite, a hitherto undescribed Mineral; a Hydrous Silicate of peculiar composition, from Carnmoney Hill, Co. Antrim, with Analysis.* By EDWARD T. HARDMAN, *F.C.S., H.M. Geological Survey.* *With Notes on the Microscopic Appearances, by* Professor E. HULL, *M.A., F.R.S.*

PART I.—This mineral occurs in abundance at Carnmoney Hill, near Belfast, in the basalt forming the old neck of a Miocene volcano. It has never been described or analysed, and has been referred to on the survey maps, and labelled in the survey collection as Obsidian, doubtless from its black colour and waxy lustre. In physical character it somewhat agrees with the Chlorophæite of Macculloch, but is entirely different in composition, which more resembles that of Delessite. From this, however, it differs essentially in colour, hardness, streak, and specific gravity. It appears, on the whole, to belong to the ferruginous-chlorite group, however.

Physical characters.—Colour, velvet black. Hardness, about 2. Brittle. Lustre, waxy, dull; streak olive brown. Before blowpipe, with difficulty fusible at edges to a black glass, which in some specimens is magnetic. Very slightly affected by strong acids, but decomposed when boiled in the powdered state in strong H.Cl. Occurs, filling amygdaloidal cavities in the basalt of Carnmoney Hill, near Belfast, and Shane's Castle, Lough Neagh.

Chemical composition compared with that of Delessite and Chlorophæite:—

	Hullite	Delessite*	Chlorophœite†
Silica, SiO_2	39·437	31·07	33·30
Alumina, Al_2O_3	10·350	15·47	—
Peroxide of Iron, Fe_2O_3	20·720	17·54	—
Protoxide of Iron, FeO	3·699	4·07	26·70
Protoxide of Manganese, MnO	trace	—	—
Lime, CaO	4·484	19·14	—
Magnesia, MgO	7·474	0·46	—
Water, H_2O	13·618	11·55	40·00
Carbonic Acid, CO_2	traces	—	—
	99·782	100·00	100·00
Formula, $R''_3R'''_4Si_6O_{21}+7H_2O$	—	—	$FeSiO_3+6H_2O$
Sp. gr.	1·76	2·89	2·02

It will be noticed that there are striking differences in the composition of the new mineral from the others. The large amount of water in Chlorophæite, and the fact that it appears to have been obtained by difference, seems to throw some doubt on the analysis.

It is difficult to express the composition of Hullite by a chemical formula.

* Dana's, 'System of Mineralogy,' 1874, p. 497.

† Ib. p. 410. Also Western Isles of Scotland. John Macculloch, M.D., p. 505.

That given above does not agree with any known types of silicate. Supposing it to be a mixture of peroxide and silicate, we should get the formula—

$$[H_6M'''_2O_6 + (M''_3M'''_2Si_6O_{18}) + 4H_2O],$$

a mixture with a meta-silicate, on the type, $H_{12}Si_6O_{18}$, corresponding with the talc and chlorite series. Or, supposing it to be a mixture of an aluminate, or ferrate, with a silicate, we get a formula not unlike that proposed for Ripidolite, viz.—

$$[M''_3Al_2O_6 + M'''_2H_6Si_6O_{18} + 4H_2O],$$

a part of the water being basic. Either of these formulas seems probable.

Its low specific gravity and its resistance to the blowpipe are remarkable, considering the large amount of iron.

The author proposes to name this mineral Hullite, after Professor Hull, who has done much valuable work in elucidating the microscopic mineralogy of the basalts of Ireland.

PART II.—*Microscopic structure of the Basalt.*—Professor Hull describes the microscopic appearance of the mineral, and of the rock in which it occurs. The basalt contains short prisms of augite imbedded in a paste of plagioclase felspar, a great deal of olivine, and the mineral desciibed above in abundance. Under the microscope, the latter is of a dark amber brown colour, nearly opaque. It permeates the whole rock, filling the interstices, and enclosing the other minerals. It does not polarize, and is, therefore, not crystalline, but assumes very much the character of amorphous chlorite, being apparently, like it also, a secondary mineral formed aftei the consolidation of the rock.

The rock contains an abundance of olivine, not seen in such quantity in any other basalt of Antrim, and hardly ever so fresh and unaltered. In most cases the outer form only is preserved; but here it is as fresh as in the lavas of Vesuvius. From this it might be inferred that the rock was comparatively recent, did we not know it to be older than the Glacial and Pliocene periods.

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3. *The Progress of the Geological Survey of Ireland. By* Professor EDWARD HULL, *M.A., F.R.S., Director.*

(With the Sanction of the Director-General.)

The author gave a short account of the progress of the Survey from its commencement in 1832, under the late General Portlock, R.E., down to the present day, stating that the whole country south of a line drawn roughly from Larne, on the coast of Antrim, to Sligo, had been surveyed, while 160 sheets of the geological map on a scale of 1-inch to the statute mile had been published.

Along with these had also been issued 78 separate Explanatory Memoirs, describing the structure and palæontology of 126 sheets. It had also been found necessary to revise the geology of the Leinster and Tipperary Coal-fields, the Carboniferous trap-rocks of County Limerick, and the south-east portion of the country, including part of Wicklow and Wexford. The coal-fields of the North of Ireland had also been surveyed, and published on maps both on the "6-inch" and "1-inch" scales; and it was also intended that the districts of County Antrim, containing the pisolitic iron ores, should be illustrated by maps on both scales. The tract still remaining to be examined included the greater portion of the counties of Donegal, Tyrone, Fermanagh, Sligo, and Antrim.

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4. *Report of the Committee on Erratic Blocks.*—See Reports, p. 185.

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5. *The Geological Relations of the Atmosphere.* *By* T. STERRY HUNT, *LL.D., F.R.S.*

The author began by noticing the inquiries of Ebelmen into the decomposition of rocks through the influence of the atmosphere, resulting in the fixation of carbonic acid and oxygen, and discussed the question at length, with arithmetical data. He inquired farther into the fixing of carbon from the air by vegetation with liberation at the same time of oxygen both from carbonic acid and from the decomposed water, the hydrogen of which with carbon forms the bituminous coals and petroleums. It was shown that the carbonic acid absorbed in the process of rock-decay, during the long geologic ages, and now represented in the form of carbonates in the earth's crust, must have equalled probably two hundred times the entire volume of the present atmosphere of our earth. This amount could not, of course, exist at any one time in the air; it would at ordinary temperature be liquefied at the earth's surface. When came this vast quantity of carbonic acid which must have been supplied through the ages? The hypothesis of M. De Beaumont, who supposed a reservoir of carbonic acid stored up in the liquid interior of the planet, was discussed and dismissed. The gas now evolved from the earth's crust from volcanic and other vents was probably of secondary origin and due to carbonates previously formed at the surface.

The solution of the problem offered by the author is based upon the conception that our atmosphere is not terrestrial, but cosmical, being a universal medium diffused throughout all space, but condensed around the various centres of attraction in amounts proportioned to their mass and temperature, the waters of the ocean themselves belonging to this universal atmosphere. Such being the case, any change in the atmospheric envelope of any globe, whether by the absorption of the disengagement of any gas or vapour would, by the laws of diffusion and static equilibrium, be felt everywhere throughout the universe, and the fixation of carbonic acid at the surface of our planet would not only bring in a supply of this gas from the worlds beyond, but, by reducing the total amount of it in the universal atmosphere, diminish the barometric pressure at the surface of our own and of all other worlds.

This conception of a cosmical atmosphere of which our own forms a part is not new, but was put forth by Sir William R. Grove in 1843, and is developed in the very learned and ingenious work of Mr. Mattieu Williams, on 'The Fuel of the Sun,' and has lately been noticed by Dr. P. M. Duncan in its geological bearings. Ebelmen, in 1845, pointed out that the greater weight of an atmosphere charged with carbonic acid would increase the temperature due to solar radiation at the earth's surface, and greatly modify atmospheric phenomena. Tyndall, by his subsequent researches on radiation, showed that certain gases, in amount too small to affect considerably the barometric pressure, might influence powerfully climatic conditions, and suggested that in the former presence, in the atmosphere, of moderate quantities of a gas like carbonic acid might be found a solution of the problem of the climates of former geologic ages. According to the author, the amount of this gas, which, since the advent of life on our earth, has been subtracted from the universal atmosphere,' although it may not have sufficed to diminish by more than a small fraction the pressure at the earth's surface, would account for all the conditions of geological history so far as temperature and climate are concerned.

He maintains that while we have evidence of a warm or sub-tropical climate prevailing over the Arctic regions from the Carboniferous down to the Lower Cretaceous times, and a gradual refrigeration up to the temperate climate of the Miocene age, we had for the first time in the Pliocene age the evidence of Arctic cold, which, with some variations, has continued until now. Since that date geographical variations have caused and may again cause local climatic changes of considerable magnitude; but no such changes could permit the existence, over continental areas within the Arctic circle, of such tropical vegetation as we know to have once flourished there. Geographical changes, as Dr. F. Campbell Dawson and others have so well pointed out, might lift large areas into the region of perpetual frost, and thus give rise to local glacial phenomena, and may, moreover, account for con-

siderable local climatic variations at the sea level since the Pliocene age. We cannot, however, account in this way for the warmer climates of previous ages, but must seek for their cause in the former constitution of the atmosphere.

Touching the suggestion that former climatic changes were due to a displacement of the earth's axis of rotation, the author expressed the opinion that it is irreconcilable with the fact, long ago insisted upon by him, that "the direction of the Arctic currents, which are guided by the earth's rotation, appears, from the distribution of marine sediments, to have been the same since very early periods." Dawson has reinforced this argument by recalling the fact that the southward migration of successive floras shows, in like manner, that from the Devonian age the general courses of oceanic currents, and consequently the position of the earth's axis, have not changed.

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6. *Report of Committee on the Conductivity of Rocks.*

See Reports, p. 133.

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7. *On the Saurians of the Dakota Cretaceous Rocks of Colorado.* *By* Professor E. D. COPE.

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8. *Notes on Eribollia Mackayi, a New Fossil from the Assynt Quartzite in the North-Western Highlands of Scotland. By* JAMES NICOL, *F.R.S.E., F.G.S., Professor of Natural History in the University of Aberdeen.*

The remarkable fossils to which the above name has been given were found on the western shore of Loch Eriboll by Mr. Donald Mackay, of Portnacow, in a portion of the Assynt quartzite, or middle deposit of the west coast series of strata. On a small block (of 9 inches by 7) more than a dozen peculiar bodies are seen running down into the interior. They are mostly rounded and conical in form, and show a central core, covering about half the width, and enclosed in an outer wall. One of the most regular measures about 1½ inch above, and 3½ inches long to the point below. Others are smaller, but similar in form and structure. Some of them occur single, but others are joined in twos or threes, and arranged as if in parallel rows. One of the largest, about 2 inches across, is more square in form, and does not taper as it descends.

The single conical forms much resemble Orthoceratites, but show no trace of septæ or partitions; whilst the internal appearance and mode of grouping rather inclines the author to regard them as corals, approximating, in form at least, to Cyathophyllidæ. A similar fragment, found some years ago in the quartzite at Ullapool, shows no structure when polished. As they differ very widely from any known organism, he has named them *Eribollia*, from the locality, *Mackayi*, from their discoverer. Some of the curious bodies, formerly described as casts of annelid tubes may, he thinks, also prove similar corals. From the Ullapool quartzite he has also a whorled shell (Macluria?).

The author in conclusion stated that he still adheres to his published views of the structure of the North-Western Highlands.

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9. *On the Influence that Microscopic Vegetable Organisms have had on the Production of some Hydrated Iron Ores. By* M. ALPHONSE GAGES.

Geologists are aware of the influence some microscopic animal living organisms have in the formation of bog iron ore, resulting from the iron of surrounding decomposing rocks, and also of the properties that the skeletons of these organisms communicate to the iron.

There are also other deposits of iron ores, far more important, and which cover immense tracts of land, especially in the tertiary formations; many of them are remarkable for their purity, and are free from *débris* of former rocks.

Under what influence were some of these so-called limonites, or brown hematites, formed? This problem can, I believe, be more or less solved by the observation of a phenomenon going on in some of the large iron tanks holding Vartry water.

We have in the College of Science, Dublin, a large iron tank on the roof of the house, into which a constant supply of water flows freely. After a certain lapse of time, the bottom of the tank and also the sides are covered with sponge-like concretions, assuming the various shapes of the well-known concretions of lime or iron ore found in various geological formations. The above sponge-like deposits are, in our case, nothing else but vegetable microscopic organisms—billions, I may say, of thread moulds, *Penicillia.*

These organisms accumulate after many months to such an extent as to form an immense sponge intercepting the flow of water. Nevertheless, in the case of the iron tank, the water remains pure and pleasant to drink, and is without any taste of iron.

These organisms have, I may say, assimilated the iron (as hydrated sesquioxide) and made of it a part of their constitution

During the process of life they have consumed the carbonic acid, and they leave as a last result, when dried in a water-bath, a pure ore of iron, containing a mere skeleton of carbon, and having a formula corresponding to that of brown hematite.

WEDNESDAY, AUGUST 21, 1878.

The following Papers were read:—

1. *On the Age of the Crystalline Rocks of Donegal.* *By* Professor W. KING, *D.Sc.*

2. *On the Correlation of Lines of Direction on the Globe, and particularly of Coast Lines.* *By* Professor J. P. O'REILLY.

The forces which have acted from the interior of the globe have been the most important of those which have produced the present distribution of land and water at its surface.

Those forces are more essentially, contraction due to secular cooling, and gravitation. Furthermore, the mineral constitution of the earth's crust has necessarily influenced the mode of action of those forces, and assuming that constitution to be homogenous, and to be represented by the lavas modern and ancient, we might expect that the contraction forms presented by those lavas when in great mass would represent the forms to which secular contraction gives rise at the surface of the earth, and that these would be limited by lines of direction presenting polygonal forms somewhat as the contraction forms of the older lavas (basalts and trachytes). Those lines of direction would represent the joints or fissures along which the interior forces have exercised their greatest action, that is, those lines which are represented on the globe by mountain chains. Now these influence notably the forms of the continents as represented by the present distribution of land and water. On the other hand, the boundaries of seas past and present have been and are simply coast lines determined by the intersection of the sea surface with the upraised strata, whose direction is essentially represented by that of the adjacent mountain chains, and of the system of fissures or joints forming their axes. Thus mountain chains and coast lines can be correlated.

Having measured a series of blocks of basalt at the Giant's Causeway, I have found that the dominating polygonal angle, or that one which most frequently occurs, is the angle 110°, and its supplement 70°; moreover, that the form presented by an isosceles triangle having 70° and 70° at the base, and 40° at the summit, is markedly present in the basalt columns of Fair Head. This form I had previously recognised as continually occurring on maps, especially geological, and have thereon based a system of correlation of lines of direction.

Adopting as line of departure, the direction of the East Coast of Madagascar, and taking this from Imray's most recent chart, I have found that the greater number of lines of direction of coasts and mountain chains on the earth's surface can be derived therefrom solely by the intervention of the angle 40° and its multiples, and 70°, and as proof have transferred from the globe those lines to maps, both geographical and geological, and found such lines to be related with many others on the map through the intermediary of those angles, and that this law is general. Amongst the many maps which might be exhibited in proof thereof, I would mention Haidinger's Geological Map of Austria, whereon occur marked lines of direction which can be most distinctly reduced to this law, as also the maps of the Geological Survey of Great Britain and Ireland.

3. *Concerning the Extent of Geological Time.* *By* Rev. M. H. Close, *F.G.S.*

This paper was only intended to afford desired opportunity for *vivâ voce* discussion on the above subject. Since geology has her own strong and unrefuted arguments for the great extent of geological time, it is not logically necessary for her to do more than to show, if it can be shown, that the physical arguments for the very inconvenient restriction thereof rest upon still unproved assumptions. The argument from the rate of cooling of the earth seems to have been satisfactorily shown by Mr. T. Mellard Reade to be quite inconclusive. The argument from the probable duration of the sun's radiation of heat assumes, *inter alia*, that the original nebula from which the solar system was formed was cold, and also that the unit of gravitation, relatively to the mass of that system, has been constant from the time when that mass began to fall together, and throughout the enormous interstellar distance which has doubtless been traversed by it since that time. Dr. Croll's suggestion in answer to the former of these assumptions is logically sufficient as a reply to the whole of this argument. Nevertheless, it may be added, as to the latter assumption, that those physicists who have entered upon certain speculations as to the cause of gravitation cannot deny that it is perfectly credible, and even probable, that gravitation is not an essential accompaniment of matter, and that the unit of gravitation may not be constant throughout all time and space. The argument from the earth's figure in connection with the retardation of her rotation by the ocean tides depends upon the doctrine of the steel-rigidity of the earth taken as a whole, as do also the calculations of various writers on subjects which bear, in different ways, on the present one. However, Sir W. Thomson himself has greatly weakened the support of this doctrine. But geology (as regards the matter in hand) is not concerned to question it; although it is, at first sight, a difficulty. The results obtained by the Tide Committee of the Association point to the conclusion that there is an 18·6 year-tide in the body of the earth depending upon the revolution of the moon's nodes, and that the rigidity of the earth, even if it be, in one sense, as high as that of steel, is yet a *viscous* rigidity, by which she may yield almost indefinitely to sufficient long-continued straining forces. Other considerations confirm this latter position. This 18·6 year-tide, whether resulting from such *viscosity* proper, or from plasticity of a different kind, must cause a variation in the earth's rate of rotation having the same period. This variation would probably be sensible if looked for by the astronomers, who would confer a boon on the geologists by endeavouring to detect it. Dr. John Evans's suggestion of the possibly considerable mobility of the axis of rotation relatively to the body of the earth bears in certain ways on the present question; the mechanical objection to it, already greatly weakened by Rev. O. Fisher, might be quite removed by the investigation suggested.*

4. *On the Earth's Axis.* *By* Rev. Professor Haughton, *M.D.*, *F.R.S.*

5. *Geological Results of the late British Arctic Expedition.* *By* Captain Feilden, *R.A.*, *and* Mr. De Rance.

The author describes Laurentian gneiss of Cape Sabine, and the Cape Rawson beds of Grinnell Land; the overlying Silurian rocks; the Devonian rocks of Dana Bay; the Carboniferous Limestone of Feilden Peninsula, and the Miocene beds of Lady Franklin Bay; the Pleistocene deposits and glaciation of the coasts of Grinnell; and the method of formation of the Icefoot.

He discusses the bearing of these results on what was already known on Arctic geology.†

* See 'Geological Magazine,' Oct. 1878.

† See 'Quart. Jour. Geol. Soc.' vol. xxxiv. p. 556.

SECTION D.—BIOLOGY.

PRESIDENT OF THE SECTION—Professor W. H. Flower, F.R.S., F.L.S., F.G.S.

Department of Zoology and Botany.

THURSDAY, AUGUST 15, 1878.

Professor FLOWER gave the following Address, entitled:—
A Century's Progress in Zoological Knowledge:—

ON the 10th of January, 1778, died the great Swedish naturalist, Charles Linné, more commonly known as Linnæus, a name which will ever be mentioned with respect and regard in an assembly devoted to the cultivation of the sciences of Zoology and Botany, as whatever may be the future progress of those sciences, the numerous writings of Linnæus, and especially the publication of the *Systema Naturæ*, can never cease to be looked upon as marking an era in their development. That work contained a systematic exposition of all that was known on these subjects expressed in language the most terse and precise. The accumulated knowledge of all the workers at Zoology, Botany, and Mineralogy since the world began, was here collected together by patient industry, and welded into a complete and harmonious whole by penetrating genius.

Exactly a century has passed since Linnæus died. What of the progress of the subjects to which he devoted his long and laborious life? This one century is a brief space compared with the ages which have passed since man began to dwell upon the earth, surrounded by living objects, which have, more and more as time rolled on, awakened his curiosity, stimulated his faculties to observe, and impelled him to record the knowledge so gained for the benefit of those to come. How does it stand in comparison which those which preceded it, in the contributions it has thus acquired and recorded?

It may be not without interest in commencing our work at this meeting to cast our eyes back and take stock, as it were, of the knowledge of a hundred years ago, and of that of the present time, and see what advances have been made; to look at the living world as it was known to Linnæus and as it is known to ourselves. The *Systema Naturæ*, the last edition of which, revised by the author, was published in 1766, will be a convenient basis for the comparison; but as the subject is one which, even in a most superficial outline, might reach such lengths as would well tire out the most patient of audiences, and absorb time which will be more profitably occupied by the valuable contributions which are forthcoming from other members of the Association, I will merely take a small section of the work, about 100 pages out of the first of the four volumes, those devoted to the first class MAMMALIA. The comparison of this part is perhaps the easiest, as the contrast is the least striking, and the progress has been comparatively the slowest. The knowledge of large, accessible, and attractive-looking animals had naturally preceded that of minute and obscure organisms, and hence, while in many other departments the advance has altogether revolutionized the knowledge of Linnæus, in the Verte-

brated Classes, especially the one of which I shall now speak, it has only extended and reformed it.

In taking the *Systema Naturæ* of Linnæus, the comparison is certainly carried back somewhat beyond the hundred years which have elapsed since his death, and the brilliant contributions to the knowledge of the Mammalia of Buffon and Daubenton just then beginning to be known, and the systematic compilation of Erxleben (published in 1777), are ignored; but for the present purpose, especially considering the limited time at my disposal, it will be best not to go beyond the actual text of the work in question.

Before considering systematically the different groups into which Linnæus divides the class, I must remark in passing upon what is the greatest, and indeed most marvellous difference between the knowledge of Zoology of our time and that of Linnæus. Now we know that the animals at present existing upon the earth are merely the survivors of an immensity of others, different in form, characters, and mode of life, which have peopled the earth through vast ages of time, and to which numerically our existing forms are but infinitesimally small, and that the knowledge we possess of an immense number of them, fully justifies the expectation of an enormous further advance in this direction. In the time of Linnæus the existence in any past time of a species having no longer living representatives on the earth, though perhaps the speculation of a few philosophical minds, had not been received among the certainties of science, and at all events found no place in the great work we are now considering.

In the twelfth edition of the *Systema Naturæ* we find the class MAMMALIA divided into seven orders: I. *Primates*, II. *Bruta*, III. *Feræ*, IV. *Glires*, V. *Pecora*, VI. *Belluæ*, VII. *Cete*. These orders contain forty genera without any intermediate subdivisions. The genera are again divided into species, of which the total number is 220.

The first order, PRIMATES, contains four genera: *Homo*, *Simia*, *Lemur*, and *Vespertilio*.

The vexed question of man's place in the zoological system was thus settled by Linnæus. He belongs to the class *Mammalia*, and the order *Primates*, the same order which includes all known monkeys, lemurs, and bats: he differs only generically from these animals. But then we must remember that the Linnæan genera were not our genera, they correspond usually to what we call families, sometimes, to entire orders. So that practically man's position is much the same as that to which, after several vicissitudes, as his separation as an order by Blumenbach and Cuvier, or as a subclass by Owen, he has returned in the systems of nearly all the zoologists of the present day who treat of him as a subject for classification upon zoological and not metaphysical grounds.

Yet since the time of Linnæus the whole science of Anthropology has been created. There is certainly an attempt at the division of the species *Homo sapiens* into six varieties in the *Systema Naturæ*, but it has scarcely any scientific basis. Zoological Anthropology may be said to have commenced with Blumenbach, who, it is interesting to recall as an evidence of the rapid growth of the science, was a contemporary with most of us in this room, for he died as lately as 1840, although his first work on the subject, '*De generis humani varietate nativa*,' was published three years before the death of Linnæus, too late, however, to influence the work we are now speaking of. The scientific study of the natural history of man is therefore, we may say, but one century old. To what it has grown during that time you are probably aware. Scarcely an important centre of civilisation in the world but has a special Society devoted to its cultivation. It forms by itself a special department of the Biological Section of our Association—a department of such importance, that on this occasion no less distinguished a person than a former most eminent President of the whole Association was thought fit to take charge of it. From him you will doubtless hear what is its present scope, aim, and compass. I need only remind you that except the one cardinal point of the zoological relation of man to other forms of life, which Linnæus appears to have appreciated with intuitive perception, all else that you will now hear in that department was not dreamt of in his philosophy.

As might naturally be supposed, apes and monkeys have, for various reasons, attracted the attention of observers of nature from very early times, and consequently Linnæus was able to give rather a goodly list of species of these animals, amounting to thirty-three; but of their mutual affinities, and of the important structural differences which exist between many of them, he seems to have had no idea, his three divisions being simply regulated by the condition of the tail, whether absent, short, or long.

We now know that the so-called Anthropoid or man-like apes, the gorilla, chimpanzee, orang, and gibbons, form a group apart from all the others of such importance, that everything related to their history, structure, and habits has been most assiduously studied, and there is now an immense literature devoted to this group alone. Nothing could better illustrate the advances we have made in a hundred years, than the contrast of our present knowledge of these forms with that of Linnæus. It is true that, as shown in the most interesting story of the gradual development of our knowledge relating to them in the first chapter of Huxley's 'Man's Place in Nature,' the animal now called gorilla was, without doubt, the pongo, well known to, and clearly described by our countryman, Andrew Battle, a contemporary of Shakespeare; and that a really accurate and scientific account of the anatomy of the chimpanzee had been published as far back as 1699 by Dr. Edward Tyson, who, as the first English comparative anatomist, I am proud to claim as in some sort a predecessor in the chair I have the honour to hold in London, as he is described on the title-page of his work as "Reader of Anatomy at Chirurgeons' Hall."

Linnæus was, however, not acquainted with these, and his second species of the genus *Homo*, *H. troglodytes*, and his first of the genus *Simia*, *S. satyrus*, were both made up of vague and semi-fabulous accounts of the animals now known as chimpanzees and orangs, but hopelessly confounded together. Of the gorilla, and what is stranger still, of any of the large genus of gibbons, or long-armed apes of South-eastern Asia, he had at the time he revised the *Systema* no idea.

The remaining monkeys, we now know, fall into three very distinct sections: the *Cercopithecidæ* of the Old World, and the *Cebidæ* and *Hapalidæ* of the New, or by whatever other names we may like to designate them. Although members of all three groups appear in the list in the *Systema*, they are all confusedly mixed together. Even that the American monkeys belong to a totally different stock from those of the Old World, does not seem to have been suspected.

The genus *Lemur* of Linnæus comprehends five species, of which the first four were all the then known forms of a most interesting section of the Mammalia. These animals, mostly inhabitants of the great island of Madagascar, though some are found in the African continent, and others in some of the Southern and Eastern parts of Asia, constitute a well-defined group, but one of which the relations are very uncertain. At one time, as in the system of Linnæus, they were closely associated with the monkeys. As more complete knowledge of their organization has been gradually attained, the interval which separates them structurally from those animals has become continually more evident, and since they cannot be placed within the limits of any of the previously constituted orders, it has been considered advisable by some naturalists to increase the ordinal divisions in their behalf and to allow them to take rank as a distinct group, related to the *Primates* on the one hand, and to the *Carnivora* and *Insectivora* on the other. The knowledge of their relations, however, bids fair to be greatly increased by the discoveries of fossil forms lately made both in France and America, some of which seem to carry their affinities even to the *Ungulata*.

Existing upon the earth at present, besides the more ordinary Lemurs to which the species known to Linnæus belong, there are two aberrant forms, each represented by a single species. These are the little *Tarsius* of Borneo and Celebes, and the singular *Chiromys*, or Aye-aye, which, though an inhabitant of the head-quarters of the group, Madagascar, and living in the same forests and under the same conditions as the most typical Lemurs, exhibits a most remarkable degree of specialization in the structure both of limbs and teeth, the latter being modified so as to resemble, at least superficially, those of the Rodents, a group with which in fact it was once placed. It was discovered by Sonnerat in Madagascar in 1780, two

years after the death of Linnæus. The specimen brought to Paris by this traveller was the only one known until 1860. Since that date, however, its native land has been more freely open than before to explorers, and many specimens have been obtained, one having lived for several years in the Gardens of the London Zoological Society.

The history of a name is often not a little curious. Linnæus applied the term *Lemures*, i.e. the departed spirits of men, to these animals on account of their nocturnal habits and ghost-like aspect. The hypothetical continent in the Indian Ocean, supposed to have connected Madagascar with the Malayan Archipelago is called by Mr. Sclater, *Lemuria*, as the presumed original home of the Lemur-like animals. Although the steps are not numerous, it might puzzle a classical scholar, ignorant of Zoology, to explain the connection between this continent and the Roman festival of the same name.

The fifth animal which Linnæus places in his genus *Lemur*, under the name of *L. volans*, is the very singular creature to which the generic term *Galeopithecus* has since been applied. It is one of those completely aberrant forms, which having no near existing relations, and none yet discovered among extinct forms, are perfect puzzles to systematic zoologists. It is certainly not a lemur, and not a bat, as has been supposed by some. We shrink from multiplying the orders for the sake of single genera containing only two closely allied species; so we have generally allowed it to take refuge among the *Insectivora*, though without being able to show to which of that somewhat heterogeneous group it has any near affinities.

The fourth genus of the PRIMATES is *Vespertilio*, comprising six species of bats. This genus has now by universal consent expanded into an order, and one of the best characterized and distinctly circumscribed of any in the class: indeed, those who have worked most at the details of the structure of bats find so much diversity in the characters of the skull, teeth, digestive organs, &c., associated with the modification of the forelimbs for flight common to all, as almost to entitle them to be regarded rather as a sub-class. Anatomical, as well as palæontological evidence, show that they must have diverged from the ordinary mammalian type at a very far distant date, as the earliest known forms, from the Eocene strata, are quite as specialized as any now existing, and no trace has hitherto been discovered of forms linking them to any of the non-volant orders. By the publication within the last few weeks of a valuable monograph on the existing species of the group, entitled "A Catalogue of the Chiroptera in the Collection of the British Museum," by G. E. Dobson, we are enabled to contrast our present knowledge with that of the time of Linnæus. Although the author has suppressed a large number of nominal species which formerly encumbered our catalogues, and wisely abstained from the tendency of most monographists to multiply genera, he describes four hundred species, arranged in eighty genera: nearly double the number of species, and exactly double the number of genera, of the whole class MAMMALIA in the *Systema Naturæ*, and these Dr. Gunther remarks in his Preface are probably only a portion of those existing. The small size, nocturnal habits, and difficulty of capture of these animals, are sufficient reasons for the supposition that there are still large numbers unknown to science. In the list of Linnæus, the first primary group of Dobson, the *Megachiroptera*, now containing seventy species, is represented by a single one, *V. Vampyrus*, obviously a *Pteropus*, to which the blood-thirsty habits of the fabulous Vampyre are attributed, but which is not absolutely identified with any one of the known species. The other species described by Linnæus can almost all be identified with bats at present well known.

A curious example of the results of basing classification upon a few, and those somewhat artificial characters, is afforded by one of the true bats, now called *Noctilio leporinus*, though admitted by Linnæus to be '*simillimus vespertilionibus, similiter pedibus alatus*, being separated from the others, not only generically, but even placed in another order, that of the GLIRES or Rodents, because it did not, or was supposed not, to fall under the definition of the order PRIMATES, which begins '*Dentes primores incisores superiores IV. paralleli.*' In reality this bat has four upper incisors, but the outer ones are so small as to have been overlooked when first examined. But even, if this were not so, no one would now dream of basing

an animal's position upon such a trivial character when opposed to the totality of its organization and habits.

The characters of the incisor teeth are placed in the first rank in the definitions of all the orders in the *Systema Naturæ*, and hence the next order called BRUTA, characterized by '*dentes primores nulli superius aut inferius*,' contains a curious mixture of heterogeneous animals, as the names of the genera *Elephas*, *Trichechus*, *Bradypus*, *Myrmecophaga*, *Manis*, and *Dasypus* will indicate. It contains, in fact, all the animals then known comprised in the modern orders of *Proboscidea*, *Sirenia*, and *Edentata*, together with the walrus, one of the *Carnivora*. The name BRUTA has been revived for one of these orders, that more generally called *Edentata*, but I think very inappropriately, for it was certainly not equivalent, and if retained at all, should rather belong to the *Proboscidea*, as *Elephas* stands first in the list of genera, and was probably in the mind of Linnæus when he assigned the name to the group.

It is curious to find that the striking differences between the African and the Indian elephants, now so well understood by every beginner in Zoology, and all the facts which have already been accumulated relating to the numerous extinct forms of Proboscideans, whether Mammoths, Mastodons, or Dinotheria, were quite unknown to Linnæus. One species only, *Elephas maximus*, represented in the zoology of a hundred years ago, was all that was known of the elephants or elephant-like animals.

The genus *Trichechus* of this edition exhibits a very curious phase of zoological knowledge: It contains two species. 1. *T. rosmarus*, the Walrus, now known to be a modified seal, and therefore a member of the Linnæan order FERÆ, and 2. *T. manatus*, a name under which were included all the known forms of Manatees and Dugongs, in fact the whole of the modern order *Sirenia*; animals widely removed in all essential points of their organization from the walrus, with which they are here generically united. Their position, however, between the elephant on the one hand and the sloths on the other, is far better than their association with the *Cetacea*, as in Cuvier's system, an association from which it has been most difficult to disengage them, notwithstanding their total dissimilarity, except in a few external characters. Although the discovery of many fossil forms has done much to link together the few existing species and to show the essential unity of the group, it has thrown no light upon their origin, or their affinities to other mammals. They still stand, both by their structure and their habits, a strangely isolated group, and it baffles conjecture to say whence they have been derived, or how they have attained their present singular organization.

The remaining genera of the Linnæan order BRUTA constitute the group out of which Cuvier, following Blumenbach, formed his order *Edentata*, a name certainly not happily chosen for a division which includes species like the great Armadillo, having a larger number of teeth than any other land mammal, but which, nevertheless, has been so generally adopted, and is so well understood, that to attempt to change it would only introduce an element of confusion. Four out of five of the principal modifications of form in the group at present known, are indicated by the four Linnæan genera, *Bradypus* or Sloth, *Myrmecophaga* or Anteater, *Manis* or Pangolin, and *Dasypus* or Armadillo. The advances during the century have consisted in the accumulation of a great mass of details respecting these groups; the addition of a fifth and very distinct existing form, the *Orycteropus* or Cape Anteater; and the discovery of numerous and very remarkable extinct forms, such as the Megatheriums and Glyptodons of South America, so fully known by their well-preserved osseous remains. There is, however, still much to be done in working out the real relationship of the somewhat isolated members of the order, if it be a natural order, both to each other, and to the rest of the Mammalia, from which they stand widely removed in many points of organization.

The third order of Linnæus, FERÆ, contained all the then known animals, which, with whatever diversities of general structure, agreed in their predatory habits, and possessed certain general characters of teeth and claws to correspond, though the terse definition of "*Dentes primores superiores sex, acutiusculi, canini solitarii*," is by no means universally applicable to them. This order was broken

up by Cuvier into the orders *Carnivora* and *Insectivora*, and the genus *Didelphys*, included in it by Linnæus, has been since by universal assent removed to another group.

The first six genera belong to the very well-defined and probably natural group now called *Carnivora*. The one placed at the head of the list, *Phoca*, is equivalent to the large and important modern sub-order *Pinnipedia*, the walrus, however, though essentially a seal, having been, as before mentioned, relegated by Linnæus to another order, on account of its aberrant dentition. But three species are recorded in the genus: *P. ursina*, the sea-bear of the North Pacific (now *Otaria ursina*); *P. leonina*, founded on Anson's sea-lion, now commonly called the elephant seal, or sea-elephant (*Macrorhinus proboscideus*, or more properly *leoninus*); and *P. vitulina*, the common seal of our coasts.

The terrestrial sub-order of *Carnivora* is represented by five genera: 1. *Canis*, including the dog, wolf, hyæna, fox, arctic fox, jackal, &c. 2. *Felis*, with only six species, but still one of the few Linnæan genera, which covers exactly the same ground as at present in the opinion of the majority of zoologists, although it may be mentioned as an example of the tendency towards excessive and unnecessary multiplication of generic names which exists in some quarters, that it has been divided into as many as fourteen. 3. *Viverra*, a heterogeneous group, containing ichneumons, coatis, and skunks, animals belonging to three very distinct families, according to modern ideas. 4. *Mustela*, a far more natural group, being nearly equivalent to the modern family *Mustelidæ*; and, lastly, a very comprehensive genus *Ursus*, consisting of *U. meles*, the badger, *U. lotor*, the racoon, *U. luscus*, the wolverene, and all the true bears known, comprised in the single species *U. arctos*. Many interesting forms of *Carnivora*, as *Cryptoprocta*, *Proteles*, *Eupleres*, *Ailurus*, and *Ailuropus*, have no place in the Linnæan system, being comparatively modern discoveries. The very recent date (1869) at which the last-named remarkable animal was made known to science by the enterprising researches of the Abbé David into the Fauna of Eastern Thibet, gives hope that we may not yet be at the end of the discovery of even large and hitherto unsuspected forms of existing mammals.

Next in the Linnæan system comes the genus *Didelphys*, constituted for the reception of five species of American opossums. This is a very interesting landmark in the history of the progress of the knowledge of the animal life of the world, as these five opossums, forming a genus in the midst of the order FERÆ, were all that was then known of the great sub-class *Marsupialia*, now constituting a group entirely apart from the ordinary members of the class. It is difficult now to imagine an animal world without kangaroos, without wombats, without phalangers, without thylacines, without dasyures, and so many other familiar forms, and yet such was the animal world known to Linnæus. It is true that a species of kangaroo from one of the islands of the Austro-Malayan Archipelago was described as long ago as 1714 by De Bruyn, who saw it alive at the house of the Dutch governor of Batavia, and that Captain Cook and Sir Joseph Banks saw and killed kangaroos on the east coast of Australia in 1770, and had published figures and descriptions of them in 1773, or five years before the death of Linnæus, but the work we are now considering contains no traces of knowledge of the existence of such a remarkable and now so well-known animal.

The three remaining genera of FERÆ, *Talpa*, *Sorex*, and *Erinaceus*, contained all the known species of the present order INSECTIVORA, which now embraces many and very varied forms, quite unsuspected a century ago, and to which it is probable that others will be added by the time the exploration of the animal products of the world is completed.

The fourth order, GLIRES, has remained practically unchanged to our day, although the name *Rodentia* has generally superseded that bestowed upon it by Linnæus. The five genera of the *Systema Naturæ*, *Hystrix*, *Lepus*, *Castor*, *Mus*, and *Sciurus*, have been vastly increased, partly by subdivision and partly by the discovery of new forms. *Noctilio* is, as before mentioned, removed to the Chiroptera, but its loss is well compensated for by *Hydrochærus*, the well-known Capybara, the largest existing member of the group, which in the Linnæan system is placed among the Belluæ, in the same genus with the pigs.

The fifth Linnæan order, PECORA, is a fairly natural group, equivalent to Cuvier's *Ruminantia*; but it is no longer considered of the value of an order, since the animals composing it have now been shown to be as closely related to certain of those belonging to the next order as they are to each other. The first genus, *Camelus*, contains both the American Lamas and the Old World camels, the demonstration of the common origin and close affinities of which has been one of the important results of the recent discoveries in the palæontology of the Western continent. In the next genus, *Moschus*, were placed the well-known musk deer of the highlands of Central Asia, and two small African antelopes, which have no special affinity with it. The subsequent inclusion in the same genus of the small chevrotains (*Tragulinæ*), which was very natural at the time, as they agree perfectly with the musk in the absence of horns and the presence of large canine tusks, by which artificial characters the genus was defined by Linnæus, was one of those unfortunate associations which has greatly retarded the progress of knowledge of the true affinities of the group. Judging by the popular works on Zoology, it is still as difficult to apprehend that a chevrotain is not a musk deer, as it is that a manatee is not a cetacean; both errors of the same kind, if not quite so gross, as that of regarding a whale as a fish, or a bat as a bird. The genus *Cervus* contains six species of true deer, including the moose, reindeer, red deer, fallow and roe, associated with the giraffe.

The twenty-one species at that time recognized of the great group of hollow-horned Ruminants are distributed quite artificially in three genera, *Capra*, *Ovis*, and *Bos*. Though subsequent investigations have greatly increased the number of species known, we are still in much uncertainty about their mutual affinities and generic distinctions. Being a group of comparatively modern origin, and only just attaining its complete development, variation has chiefly affected the less essential and superficial organs, and the process of extinction of intermediate forms has not operated sufficiently long to break it up into distinctly separated natural minor groups, as is the case with many of the older families, which yield, therefore, far more readily to the needs of systematic classification, especially as long as the extinct forms are unknown or ignored.

The sixth order of land mammals, BELLUÆ, corresponding to the *Pachydermata* of Cuvier, contains what is now known to be a heterogeneous collection, viz. the horses, the hippopotamus, the pigs, rhinoceros, and the rodent capybara. The abolition of these two last orders and the entire re-arrangement of the ungulate mammals, into two different natural groups, now called *Artiodactyla* and *Perissodactyla*, first indicated by Cuvier in the 'Ossemens fossiles,' from the structure of the limbs alone, and afterwards confirmed by Owen from comparison of every part of the organization, has been one of the most solid advances made in our knowledge of the relations of the Mammalia during the present century.

The past history of this, as of so many other groups of vertebrated animals, has been brought to light in an unexpected manner by the wonderful discoveries of fossil remains made during the last ten years in the Rocky Mountains of America; discoveries, the importance of which will only be fully appreciated when the elaborate and beautifully illustrated work which Professor Marsh has now in progress, is completed.

The last Linnæan order, CETE, is exactly conterminous with the order so named, or rather more generally modified to *Cetacea*, in the best modern systems, for Linnæus did not commit the error of Cuvier and others, of including the *Sirenia* among the whales. His knowledge of the animals composing the group was necessarily very imperfect, indeed it is only within the last few years, especially since the impulse given to their study by Eschricht of Copenhagen, that the great difficulties which surround the investigation of the structure and habits of these denizens of the open sea have been so far surmounted that we have begun to obtain clear views of their organization, affinities, and geographical distribution.

Two most remarkable forms of mammals, so abnormal in their organization as now to be generally considered deserving the rank of a distinct sub-class, the *Echidna* and *Ornithorhynchus*, were first made known to science in 1792 and 1799 respectively, and consequently have no place in the *Systema Naturæ*. The very recent discovery

of a third form to this group, or at least a very striking modification of one of the forms, the large New Guinea echidna (*Acanthoglossus Bruynii*), is the last important acquisition to our knowledge of the class.

In this brief review of the progress of one small section of one branch of zoological knowledge it will be seen that it is chiefly of systems of arrangement, of classification, and of names that I have been treating. By many biologists of the present day these are looked upon as the least attractive and least profitable branches of the subject. The interest of classification, though it has lost much in some senses by the modern advances of scientific biology, has, however, gained vastly in others. The idea that has now, chiefly in consequence of the writings of Darwin, taken such strong hold upon all working naturalists—the idea of a gradual growth and progressive evolution, and therefore genetic connection between all living things—breaks down the artificial barriers which zoologists raise around their groups, and shows that such names as *species*, *genera*, *families*, *orders*, &c., are merely more or less clumsy attempts to express various shades of differences among creatures connected by infinite gradations, and in this sense destroys the importance attached to them by our predecessors. On the other hand, it immensely increases the interest contained in the word "relationship," as it implies that the word is used in a real and not, as formerly, in a metaphorical sense. There is a kind of classification, such as we might apply to inanimate substances or manufactured articles. We may say, for instance, that a tumbler, a wine-glass, and a tea-cup are more closely related to each other than either one is to a chair or a table, and that they might be formed into one group, and the last-named objects be placed in a second. This kind of classification is certainly useful in its way, for methodical arrangement and descriptive purposes. It is the kind of arrangement which Linnæus and his contemporaries applied to animals. It is, however, a very different classification from that which supposes that the members of a group having common essential characters are descended from a common ancestor, and have gradually, by whatever cause or means, become differentiated from other groups. On this view a true classification, if it could be obtained, would be a revelation of the whole secret of the evolution of animal life, and it is no wonder that many are willing to devote so large a share of their energies to endeavour to attain it.

The right application of the principles of nomenclature, first clearly established by Linnæus, to the groups we form is, again, by no means to be despised, as laxity and carelessness in this respect are becoming more and more the greatest hindrances to the study of Zoology. The introduction of any new term, especially a generic name, and indeed the use of an old one by any person whose authority carries weight, has an appreciable effect upon the progress of science, and should never be done without a full sense of the responsibility incurred. All beginners are puzzled and often repelled by the confused state of zoological nomenclature to an extent to which those who have advanced so far as only to care for the things, and to whom the actual names by which they are called are comparatively indifferent, have little idea. Those whose special gift or inclination leads them to the pursuit of other branches of Biology, as Morphology, Physiology, Embryology, &c., must have definite names for the objects they observe, depict, or describe, and are dependent upon the researches of the systematic zoologist for supplying them, and should not neglect to take his counsel, otherwise much of their work will lose its value.

Several times has the British Association thought this a worthy subject for the consideration of its members, and through the instrumentality of a committee of working naturalists drew up in 1842 an excellent code of regulations and suggestions on the subject of zoological nomenclature. These rules were revised and reprinted in 1865; and in accordance with a resolution adopted at the last annual meeting at Plymouth they have been again republished at the cost of the Association during the present year. The mere issue of such rules must have had a beneficial effect, as they have undoubtedly been a guide to many careful and conscientious workers. Unfortunately there are no means of enforcing them upon those of a different class, and there is still something wanting, short of enforcing them, which possibly may be within the power of the Association to effect. In

the administration of the judicial affairs of a nation, besides the makers of the laws, we have an equally essential body to interpret or apply the law to particular cases—the judges. However carefully compiled or excellent a code of regulations may be, dubious and difficult cases will arise, to which the application of the law is not always clear, and about which individual opinions will differ. The necessary permission given in the Association rules to change names which are either 'glaringly false,' or 'not clearly defined,' opens the door to considerable latitude of private interpretation. As what we are aiming at is simply convenience and general accord, and not absolute justice or truth, there are also cases in which the rigid law of priority, even if it can be ascertained, requires qualification, and other cases in which it may be advisable to put up with a small error or inconvenience to avoid falling into a larger one. I may name such cases as the propriety of reviving an obsolete or almost unknown name for one which, if not strictly legitimate, has been universally accepted, or the retention of a name when already applied to a different genus, instead of the institution of another in its place. For instance, should the name *Echidna*, by which the well-known Monotremous Mammal is known in every text-book and catalogue in every language, be susperseded by *Tachyglossus*, because the former name had previously been applied to a genus of snakes? or should the chimpanzee be no longer called *Troglodytes* lest it should be confounded with a wren? Should *Chiromys* be discarded for *Daubentonia*, *Trichechus* for *Odobenus*, and *Tapirus* for *Hydrochœrus*? Should the Java slow lemur be called *Loris*, *Stenops*, or *Nycticebus*? Should Sowerby's whale be placed in the genus *Physeter*, *Delphinus*, *Delphinorhynchus*, *Heterodon*, *Diodon*, *Aodon*, *Nodus*, *Ziphius*, *Micropterus*, *Micropteron*, *Mesodiodon*, *Dioplodon*, or *Mesoplodon*, in all of which it may be found in various systematic lists? Should one of the largest and best known of the Cetaceans of our seas be called *Balœnoptera musculus*, *Physalus antiquorum*, or *Pterobalæna communis*, all names used for it by authors of high authority? Should the smallest British seal be called *Phoca hispida*, *fœtida*, or *anellata*?

I might go on indefinitely multiplying instances which will be answered differently by different naturalists, the arguments for one or the other name being often nicely balanced. What is wanted, therefore, is some kind of judicial authority for deciding which should in future be used. If a committee of eminent naturalists, selected from various nations, and divided into several sections, according to the subjects with which each member is most familiar, could be prevailed upon to take up the task of revising the whole of our existing nomenclature upon the basis of the laws issued by the Association in 1842, occasionally tempering their strictly legal decisions with a little discretion and common sense, and with a view, as much as possible, of avoiding confusion, and promoting general convenience; and if the working zoologists of the world generally would agree to accept the decisions of such a committee as final, we should dispose of many of the difficulties with which we are now troubled. There seems to me no more reason why the nomenclature of such a committee, if it were composed of men in whose judgment their fellow-workers would have confidence, should not be as universally accepted as is the nomenclature of the last edition of the *Systema Naturæ* of Linnæus. We have agreed not to look beyond that work for evidence of priority, and why should we not agree in the same way to accept decisions which would probably be arrived at with even fuller knowledge and greater sense of responsibility?

Whether this suggestion will be received with favour or not, it appeared to me that it was one not inappropriate for the consideration of this Section which has already dealt with the question in a manner so advantageous to science, and also for this year which has witnessed the hundredth anniversary of the death of the great teacher of systematic zoology.

Our knowledge of the living inhabitants of the earth has indeed changed since that time. Our views of their relations to the universe, to each other, and to ourselves, have undergone great revolutions. The knowledge of Linnæus far surpassed that of any of his contemporaries; but yet of what we now know he knew but an infinitesimal amount. Much that he thought he knew we now deem false. Nevertheless, some of the oldest words to be found in all his writings contain

sentiments which still claim a response in the hearts of many. Although we are less accustomed to see such words in works of science, that is no proof that their significance has been impaired by the marvellous progress of knowledge. With the words which Linnæus selected to place at the head of his great work I will conclude—

'O Jehova,
Quam ampla sunt tua opera!
Quam sapienter ea fecisti!
Quam plena est terra possessione tua!'

The following Papers were read:—

1. *Report of the Close-time Committee.*—See Reports, p. 146.

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2. *Report of the Committee on the Zoological Station at Naples.* See Reports, p. 149.

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3. *On the Geographical Distribution of the Cheiroptera. By* Dr. G. E. DOBSON.

Ordered by the General Committee to be printed *in extenso* among the Reports. See p. 158.

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4. *Notes on the Geographical Distribution and Migrations of Birds, &c., on the Northern Shores and Lands of Hudson's Bay. By* J. RAE, *M.D., LL.D., F.R.G.S.*

Dr. Rae read a long paper on the above subject, chiefly with the object of supplementing the writings of Sir John Richardson, whose descriptions are in some instances incomplete, in consequence of that admirable zoologist not having been able to visit certain localities in the Hudson's Bay Company's territory, and having had to depend upon the reports of others, who sometimes were not very conversant with the subject.

FRIDAY, AUGUST 16, 1878.

The following Papers were read :—

1. *Notes on a case of Commensalism in the Holothuria.* *By* Dr. A. F. ANDERSON.

2. *On certain Osteological Characters in the Cervidæ and their probable bearings on the past History of the Group. By* Sir VICTOR BROOKE, Bart.

3. *The Habits of Ants. By* Sir JOHN LUBBOCK, *F.R.S.*

4. *On the Habits of the Field-Vole (Arvicola agrestis,* L.). *By* Sir WALTER ELLIOT, *F.R.S.*

The species above named, more commonly known as the short-tailed field-mouse, has been observed of late to be annually increasing. In the early part of 1876, it appeared in such numbers in the hill pasture farms of the border districts between England and Scotland, and in the western parts of Yorkshire, as to cause serious damage to the grazing ground on which the sheep mainly depend for maintenance in spring, thereby inflicting serious loss on farmers by the impoverishment and death of stock. Notwithstanding the efforts of the shepherds and their dogs, assisted by an unusual influx of birds and beasts of prey—hawks, buzzards, owls, weasels, foxes, &c.—their numbers were not sensibly diminished; but on the approach of summer they began to perish with hunger after exhausting their own means of subsistence, and the few survivors were driven by starvation to their usual haunts. Their favourite abodes are low-lying humid meadows and damp plantations, in which they construct superficial burrows, breeding five or six times in the year, and producing six to eight young at a birth. Autumnal rains and severe winter frosts generally kill great numbers, and it is to an absence of these checks, during a series of mild seasons from 1872–76, that their late abnormal increase is attributed.

It is remarkable that during the same period a kindred foreign species, the *Arvicola arvalis,* Pallas, was creating similar damage to the corn-fields of Austria and Hungary, and only the other day a paragraph in the *Times* stated that they are now destroying the wheat crop in Moldavia.

Several instances are recorded of mischief done by the common vole to young plantations, notably those described by Jesse in the royal forests of Hampshire and Gloucestershire.

These facts show that although they have hitherto confined their attacks (as far as known) in our own country to woods and pastures, they may, under conditions favourable to their increase, attack our cereal produce. It would be well, therefore, for game preservers to consider whether they are not promoting such a contingency by the persistent destruction, under the name of *vermin,* of the natural enemies of the vole, and for farmers to reflect whether they may not carry too far the extirpation of the mole, of which voles are a favourite prey.

One object in offering these observations to the section was to ascertain whether anything similar had been observed in Ireland, where it is believed the vole is not common, for it is observed that it, as well as its British congeners, *A. amphibia* and *A. glareolus*, are omitted from Mr. Barrington's list of mammals given at page 91 of part ii, in the Guide to Dublin prepared for this meeting of the Association.*

* The paper of which the above is an extract will appear in the 'Transactions of the Berwickshire Naturalists' Club' for the current year.

SATURDAY, AUGUST 17, 1878.

The Department did not meet.

MONDAY, AUGUST 19, 1878.

The following Papers were read:—

1. *Report on the Present State of our Knowledge of the Crustacea.* Part IV. On Development. See Reports, p. 193.

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2. *On the* Willemoesia *Group of Crustacea. By* C. SPENCE BATE, *F.R.S.*

Among the many objects of interest taken from the depths of the ocean during the cruise of the *Challenger*, there were few that attracted more attention than the so-called blind Crustacea.

These were described by Mr. Willemoes-Suhm rather fully both in 'Nature' and in the 'Transactions of the Linnean Society,'—in the pages of the former under the name of *Deidamia*; but in the latter Mr. Grote, having discovered that this name had been in use for a genus of Sphingidæ, changed it to *Willemoesia*, in compliment to the unfortunate marine zoologist of the expedition.

Soon after it had been published it was recognized by those who had given attention to the subject to resemble a small crustacean that Dr. Heller had described among the "Crustaceen des südlichen Europa," from a single male specimen in the collection of the museum at Vienna, to which he gave the name of *Polycheles typhlops*, belonging to the same group. I believe that I am correct in stating that Mr. Wood-Mason was the first, in the 'Journal of the Asiatic Society' for 1875, to point out the resemblance between the *Polycheles* of Heller and *Willemoesia* of the *Challenger* expedition.

Each of these zoologists has described the animal as being blind; and it is supposed that on this character Heller founded the specific name of his species, the eyes of which, he says, are rudimentary; and Willemoes-Suhm says that "*the eyes are entirely wanting*, nor is there any place left open where you might expect to find them."

Both these observant naturalists have passed over the peculiar character of the organ of vision that belongs to this group of animals. Heller has classified it with the family Astacidæ in a division by itself; and they have both asserted that it closely corresponds with the fossil genus *Eryon*.

Dr. Camil Heller, moreover, says that it bears a strong resemblance in the form of the body to the 'Scyllaridæ,' from which it differs essentially by the structure of the antennæ, the form of the chelæ, and the narrow sternum. With the Astacidæ it has in common the possession of the leaf-like appendage at the base of the second antennæ and the chelate character of the pereiopoda; in all other respects it differs from *Astacus*.

Willemoes-Suhm says: "Among the living Decapoda Macrura there is hardly a group with which *Willemoesia* could be said to be very closely allied. Nearest to it are undoubtedly the "Scyllarinæ;" but these, like all the genera of the family Palinuridæ, differ from it in the absence of the lamellar appendage of the second antennæ, and in the presence of palpi at the base of the gnathopoda, which, as we have seen, are wanting in this new genus. Nor can it, for this latter reason, be referred to the Astacidæ, with which it has in common the presence of the antennal scale."

"The genus," says Heller, corresponds greatly with the fossil crustacean described by Deshayes from the slate-quarries of Solenhofen (*Eryon Cuvieri*), since

also in this are found a flattened carapace and similarly formed antennæ and pereipoda. The hinder part of the body is much narrower than the anterior; and the leaf-like appendage of the second pair of antennæ is much enlarged. It forms a link between the Scyllaridæ on the one hand, and the Astacidæ on the other."

"It is very astonishing, indeed," says Willemoes-Suhm, "that, among all the crustaceans known to us, *Willemoesia* approaches most closely the fossil Eryontidæ. If we compare, for example, our figure of *W. crucifera* with the figure of *Eryon arctiformis*, and the description of the 'Tribu des Eryons' given by Milne-Edwards (and probably taken especially from Desmarest's 'Crustacés Fossiles') we find most striking resemblances between the two forms. In *W. crucifera* as well as in *Eryon* the carapace has nearly half the length of the whole body; and in both forms its lateral borders are wing-like expansions which are divided by two deep incisions into three portions. The anterior border of the carapace is nearly straight in both forms.

"*Eryon* was probably not blind; for the eye-stalks have been found in several specimens. Its antennæ seem to be somewhat more reduced then in *Willemoesia*; but the second pair of them has, according to Desmarest, 'une écaille assez large, ovoïde et fortement échancrée.' This is the chief difference between *Eryon* and the Palinuridæ, and the same in which *Willemoesia* also differs from that group."

So much do the fossil and recent animals resemble each other that the discoverer of the recent species says, 'If the last pair of pereiopoda and the pleon of *Eryon* were presented to me I should undoubtedly declare them to be parts of the genus *Willemoesia*. There are the same line of spines at the top of the rings, the same wing-like expansions on both sides, and that characteristic 'caudal apparatus.' Also the fine fringe of hairs which distinguishes the caudal fin of *Willemoesia* is to be seen in the fossil crustacean"

"*Eryon*," continues the same author, "differs from the living genus chiefly by the presence of eye-stalks and of palpi at the base of the gnathopoda. According to Quenstedt, the latter were observed only with difficulty; and their presence seems not to be beyond all doubt." And the lamented carcinologist of the expedition looked forward to his return, when he would look over the original specimens and satisfy himself, so as to enable him to give a more detailed account of the relations of *Willemoesia* to *Eryon*. That they must be very close he had no doubt, and considered that among the Eryontidæ this new genus must take its place, between the Astacidæ and Palinuridæ.

It will be desirable that we should examine the animals and see how far the conclusions arrived at by two independent observers can be supported by extended inquiry.

Heller describes *Polycheles* as having a thin dermal structure, *rudimentary* eyes, antennæ like those of *Willemoesia*, and four pairs of pereiopoda chelate, and one (the fifth pair) simple.

Willemoes-Suhm describes *Willemoesia* as having the eyes and eye-stalks *entirely wanting;* four or five pairs of pereiopoda chelate in distinct species.

In all other respects the descriptions of the two authors agree.

The *Challenger* collection contains specimens of this group from thirteen different places; and in every one I was able, upon close examination, to find the eyes very distinct, though singularly situated. Moreover, there is a variation in form and position that gives them a value in classification, particularly when taken into consideration with the relative forms of the several pairs of pereiopoda.

The dorsal surface of the several species of this group is flattened and depressed, and the anterior margin is tolerably straight; the central tooth, which is sometimes single and sometimes double, is never directed forwards in the form of a rostrum, but upwards and obliquely forwards. In the anterior margin on each side there is a deep cleft in the dorsal surface, in which the eye with its peduncle is lodged; the anterior extremity, being directed forwards, outwards, and downwards, is covered over by the lateral projecting wings of the carapace. It appears to have two points of vision, the one upwards by the dorsal surface, the other downwards and outwards by the lens at the extremity of the peduncle. But these several points are liable to vary in degree. In some the dorsal notch is almost non-existent, in others it is very deep; and it is by this variation, taken in

connection with the power of change in the form of the pereiopoda, that I purpose classifying the several species of this interesting group.

POLYCHELES, Heller.

(Crust. des südl. Europa.)

In this genus I accept the author's definition, that it has the anterior four pairs of pereiopoda chelate and the fifth simple. But instead of saying that the eyes are rudimentary, I assert that they are immovably lodged in a notch in the dorsal surface of the carapace, with the anterior extremity projecting beneath the antero-lateral wings of the carapace.

PENTACHELES, n. g.

All the pereiopoda are chelate, and the eyes are lodged immovably in a notch in the antero-dorsal surface of the carapace, with the anterior extremity projected beneath the antero-lateral wing-like extremity of the carapace.

WILLEMOESIA, Grote.

('Nature,' October 1873.)

All the pereiopoda chelate, and the eyes immovably situated in the anterior or frontal surface of the cephalon, and neither lodged in a notch in the dorsal surface of the carapace nor covered by the antero-lateral wing of the carapace. Eyes small, directed outwards and forwards.

		Fathoms	Temp.	
	POLYCHELES.			
crucifer	West Indies	450	...	*Glob.*-ooze.
Helleri	Kermadec Island	520	6°	Hard.
,,	New Guinea	1070	2°·1	*Glob.*-ooze.
baccatus	Fiji	310	...	r.c.
typhlops	Mediterranean	...	...	...
	PENTACHELES.			
lævis	Philippine Islands	500	5°·3	*Glob.*-ooze.
Suhmi	Patagonia	120	...	Mud.
gracilis	Fiji	610	3°·7	*Glob.*-ooze.
obscurus	New Guinea	1070	2°·1	*Glob.*-ooze.
auriculatus	Fiji	610	...	*Glob.*-ooze.
enthrix	New Hebrides	315	...	r.c.
	WILLEMOESIA.			
leptodactyla	North Atlantic	1900	1°·9	*Glob.*-ooze.
,,	Juan Fernandez	1375	1°·8	*Glob.*-ooze.

The eyes of the several genera, although they may differ from each other in structural detail, yet correspond throughout the group in a common characteristic. The peduncle is reduced to a minimum and fixed as a rigid part of the dermal structure, over which a portion of the carapace is projected.

If we turn to the animal while it is yet embryonic (and our only opportunity is its observation before it has quitted the egg), although in an advanced condition, we see that previously to the eruption from the ovum it attains at least the zoëa stage of development, and that the eyes are large and distinctly pedunculated, just in the same way as the zoëa of *Alpheus* in the embryonic condition ha eyes considerably larger and more like the permanent organ in other genera than the adult parent from which it springs.

The alteration from the original type to a depauperised condition is therefore due to causes acting through the habits of the animal after it has passed through its zoëa stage. This is precisely the way that *Alpheus* has passed; and as the

result has been somewhat similar, it is highly probable that the conditions have been parallel.

Alpheus in the young stage is a free-swimming animal with powerful organs of vision; but in its adult condition it burrows in the mud of the sea-bottom, where the eyes are of little use, except to see things in close proximity, and where they are liable to injury from rough accidents, unless they be protected, as they are, by the strength of the overlying carapace.

The history of *Willemoesia* and its allies I believe to be very parallel with that of *Alpheus*. In its young stage it has well-developed eyes, which it loses when it has arrived at its adult condition. This I believe to be attributable to a similar cause, viz. that it burrows in the soft mud of the deep-sea bottom.

This is borne out by an examination of the contents of the stomach, which I found to be full of the remains of the structures found in the *Globigerina*-ooze.

That the depauperised state of the organs of vision is not due to the loss of light from the great depth at which *Willemoesia* is taken is evident from the fact that *Thalascaris*, n.g. (Cranognidæ) is taken at depths equally great, and is remarkable for the large size of its eyes.

Willemoesia, moreover, is not necessarily one of our deepest sea inhabitants. *Willemoesia leptodactyla* was taken both in the Atlantic and Pacific at a depth of 1900 and 1375, while *Polycheles Helleri* and *Pentacheles obscurus* were taken north of New Guinea at a depth of 1070; yet most of the other species, even including *Polycheles Heleri*, were taken at depths between 610 and 120 fathoms.

The bottom temperature has only been recorded in seven of the stations at which the species were taken—that is, only from the deeper soundings; these, however, vary from 6° to 1°·8 C. I am therefore inclined to think that temperature can only be second to that of the character of the sea-bottom itself.

Out of the thirteen stations from which specimens of this group have been recorded, the bottom consists of what has been named *Globigerina*-ooze in eight, one is recorded of mud, and two 'r.c.' (which, I suppose means red clay), and one only on hard ground; but as this occurs only once, and that with an animal (*Polycheles Helleri*) that is also recorded from another station where *Globigerina*-ooze exists, I think that we may safely infer that the whole group are inhabitants of a soft bottom, preferring that in which animal life suitable for their existence abounds, and that their general structure and form are in accord with their habitat.

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3. *On the supposed Radiolarians and Diatoms of the Coal-measures.** *By* Professor W. C. Williamson, *F.R.S.*

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4. *On the Association of an Inconspicuous Corolla with Proterogynous Dichogamy in Insect-fertilised Flowers.* *By* Alex. S. Wilson, *M.A.*, *B.Sc.*

It is a well-ascertained fact that the great majority of conspicuously coloured flowers are proterandrous, that is, the anthers are matured before the stigmas of the same flower. Plants where this arrangement for the prevention of self-fertilisation obtains have also for the most part their flowers growing close to each other, forming a more or less *compact* inflorescence, as in *Erica*, *Calluna*, *Vaccinium*, *Digitalis*, *Linaria*, *Gladiolus*, &c. The flowers are also in many cases all turned to one side of the floral axis, the inflorescence being termed secund. By these means the plants as a whole are rendered more conspicuous. In the indefinite or basifugal mode of flowering which is the commonest form, the flowers come out in succession from below upwards; hence on any given spike the older flowers will be lower down than the younger ones, and it follows with proterandrous dichogamy the lower flowers will at a given time be in the second or female stage, while those towards the upper extremity of the stalk will have only attained to the first or male condition. The lower flowers will in fact have shed all their pollen, and have their stigmas ready to be fertilised by the time the anthers of the upper flowers are beginning to shed pollen. On the other hand, in a plant with proterogynous

* See Section C., p. 534.

dichogamy, it is clear that, if we still keep to the indefinite mode of flowering, the lower or older flowers on any given plant will be in the second or male stage by the time the younger upper ones have reached the first or female stage, seeing that in this case the stigma is developed before the anthers of each flower. *Scrophularia nodosa* affords a good example of a plant having proterogynous dichogamy, and to it the present paper chiefly refers. In this plant the stigma, after fertilisation, is removed out of the pathway to the nectar by the bending back of the style on the outside of the corolla; thereafter the stamens straighten out to occupy the place formerly held by the stigma, and begin to shed their pollen in this position. The corolla of this flower, as usual in proterogynous plants, is small and obscurely coloured. There is also a *lax* inflorescence, the flowers not being crowded together on one side as in proterandrous and highly coloured flowers, but scattered all round, so that as a whole the plant is not easily discerned from a distance, nor does it readily strike the eye as a conspicuous object. That it is truly dependent on insects and not on the wind for the transference of its pollen, is proved by the presence of a well-developed nectariferous gland, and by its emitting odour. Its inflorescence so far agrees with the indefinite form that as a whole the older flowers (in this case male) occur lower down than the younger (female) ones. Among such inconspicuously flowered plants proterogynous dichogamy seems to prevail, just as the proterandrous is characteristic. of highly coloured flowers. Hitherto it has not been shown in what way an entomophilous or insect-fertilised plant could possibly profit by a small uncoloured corolla, nor has any reason been given why this apparent disadvantage should be generally associated with proterogynous dichogamy. The procedure of a wasp visiting *Scrophularia nodosa* afforded the solution of this problem. The manner in which it proceeded was quite exceptional. The first flower on the stem which it visited was the top one; from this it passed to the others in a somewhat irregular manner going downwards, and finally left the plant from the lowest flower. The same thing having been observed repeatedly, a key to the whole question was furnished; for any one who has watched bees collecting honey from flowers must have observed that the bee goes to the bottom flowers first, and then visits those next above on the same stalk in regular succession from below upwards. Now, that this order of visitation is of importance in reference to the cross-fertilisation of a plant, will be obvious if we bear in mind a fact which the experiments of Mr. Darwin ('Cross and Self-fertilisation,' p. 299) have clearly demonstrated, viz., that "a cross between the flowers on the same plant does not at all increase the number of seeds, or only occasionally, and to a slight degree." Now, were an insect invariably to visit first those flowers on a plant which are shedding their pollen, and then to pass to those with mature stigmas, clearly the usual result of this would be that it simply removed pollen from the anthers of the flowers in the male stage, and deposited it on the stigmas of those flowers *on the same plant* which happened to be in the female stage. The effect of this would be little or no better than self-fertilisation. This is well illustrated in the case of *Gladiolus*. In this strikingly beautiful plant we have well-marked protandry in association with a highly conspicuous perianth, while the development of the flowers is from below up, so that the older lower flowers have shed their pollen by the time that of the upper ones are ready. The anthers are at first bent forwards and downwards, so that they rub their pollen on the back of a bee entering the flower; meanwhile the immature stigma is above and behind them, quite out of the way of an insect going into the flower. When the pollen is shed, however, the stamens straighten up out of the way, while the stigma lobes expand and bend downwards and forwards, so that they stand in the fairway to the nectar ready to scrape off pollen from any insect as it passes down the tube formed by the perianth. In this case a bee entering one of the lower and older flowers has any pollen that it brings with it *from another plant* removed from its back by the pendant stigmas of these flowers, and when it ascends to the younger male flowers towards the top of the spike receives a plentiful supply of pollen previous to leaving for another plant. This pollen it will not fail to deposit on the stigmas of the female flowers which it first enters. From this it appears, then, that the whole elaborate arrangements of *Gladiolus* to ensure cross-fertilisation would be frustrated, were the insects frequenting it to begin at the top flowers and proceed downwards, instead of visiting them in the reverse order from below

up as they habitually do, for pollen would then simply be taken from the younger upper flowers, and deposited on the stigmas of those lower down the stalk. In like manner, a similar effect would result in the case of proterogynous plants, were these visited exclusively by bees or insects adhering to the ascending habit of the bee, for pollen would in that case be transferred from the lower older male flowers to the upper female ones, the insect leaving with little or no pollen to carry to another spike. Thus the chances of cross-fertilisation would be minimised, and the ends served by the flower's dichogamy, nectar, and odour would be missed. For these reasons it seems highly probable that proterogynous plants like *Scrophularia nodosa* are adapted to the visits of insects which do not possess the ascending habit of the bee, but visit flowers when in search of honey in an irregular manner, or in an order exactly the opposite of that observed by the bee, as in the case of wasps visiting *Scrophularia* before referred to. The lax inflorescence, too, favours an irregular order of visitation, for as the flowers are placed at a distance apart, it is almost impossible for an insect to visit them in perfectly regular order. We see, then, that in both cases things are so arranged that an insect on coming to a plant shall first enter a female flower, and there deposit the pollen it brings from other plants, and that before it leaves, whether a bee leaving from the top, or a wasp from the lower flowers, it is well dusted with pollen from the male flowers it last enters. According to H. Müller, the flowers of *Scrophularia* are chiefly frequented by wasps; and *S. aquatica* Mr. Darwin states to be fertilised exclusively by wasps. It seems only fair to infer that such flowers are in some way specialised to suit the nature and habits of these insects. We have thus got so far with our explanation as to see how plants having proterogynous dichogamy do not have their apparatus for cross-fertilisation rendered ineffectual, as would undoubtedly be the case were the ascending mode of visiting flowers rigidly followed and universal among all species of insects. It still remains to trace the connection of this with obscurity in the flowers, which appear to shun observation almost as distinctly as proterandrous flowers court it. Within certain limits it is an advantage as regards cross-fertilisation that a plant's visitors should be confined to a few or even to one species of insect, for an insect visiting all flowers indiscriminately would be likely to have deposited all the pollen taken from a particular species of flower on the stigmas of other and different species where it would be of no use, before coming to another plant of the same species as the first. This is probably the reason why the great majority of flowers are visited only by a very limited number of species of insects. Sir John Lubbock gives a list of plants with one species opposite each as its sole visitant; whether this be really so or not, unmistakably there is a tendency in this direction. If, then, we find a plant whose flowers secrete nectar, and ascertain that it is visited almost exclusively by certain species of insects, and if the flowers do not possess a large coloured corolla, we are at liberty to conclude that these insects are able to find such plants without its guidance, and that the materials consumed in its production can be otherwise turned to better account in the economy of the plant, just as in the case of self-fertile cleistogamic flowers. Assuming, then, that inconspicuous flowers are adapted to the visits of wasps, is there anything in the habits of these insects different from those of bees, that would afford an explanation of the remarkable fact that they appear to be able to discover a small uncoloured flower as easily as a bee can a large and conspicuous one? Wasps differ from bees in one important respect, that while the latter are exclusively vegetable feeders, the former add to their vegetable diet by preying on insects smaller than themselves. All through the animal kingdom carnivorous animals are endowed with keener powers of scent and vision than graminivorous creatures. Indeed, it is a direct result of natural selection that a creature whose food is perpetually eluding it should in time acquire acuter perceptive powers than one whose food is more easily obtained. That keenness of vision, then, which enables a wasp to descry its prey at a distance, aided by an acute sense of odour, in all probability also enables it to discover these obscure flowers without the guidance afforded by a large coloured corolla. This obscurity, therefore, specially adapts these flowers for fertilisation by wasps to the exclusion of insects less highly endowed in these respects; while the wasp gains this advantage, that it has an increased chance of finding honey in such flowers on account of the likelihood of

their being overlooked by other honey collecting insects. For this reason wasps, as Mr. Darwin observes, do not frequent coloured flowers to the same extent that bees do, as they probably meet so often with disappointments in the way of flowers that have been emptied of their nectar previously. Hence it appears that the bee is more highly specialised as a collector of honey than the wasp.

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5. *On the Nectar of Flowers. By* ALEX. S. WILSON, *M.A., B.Sc.*

Some observations on this subject made by the author during the past summer revealed several highly interesting points connected with the labours of an insect collecting honey. These are attended with more difficulties than might at first sight be supposed, for it appears that nectar is only produced during certain states of the atmosphere—dry warm weather being most favourable. The industry of the bee is probably indispensable to its existence, as a small quantity of honey represents a very large number of flowers visited. In the case of the common red clover, 125 heads were found by analysis to give one gramme of sugar. Now, as each head contains about sixty florets, even in this plant, which is comparatively rich in nectar, 7,500,000 distinct flower-tubes must be sucked for each kilogram of sugar collected. This corresponds to about two and a half millions of visits for a pound of honey. In most of our common flowers the amount of nectar is much smaller, usually dilute and in many cases absent; moreover, in some instances it appears to be formed only when the essential organs are mature. If in addition the class of sham nectar producers, which is perhaps larger than has been supposed, and previously emptied flowers, as well as those whose nectaries are inaccessible, be taken into account, it will be seen that a great number of fruitless visits must be made by these insects. Bees, however, do not visit any flower at random, but appear to know which flowers are secreting and which are not, on any particular day. Thus, the flowers of *Vaccinium Myrtillus* were thronged with bees while those of *Ulex Europæus* were unvisited, on a day when the former were secreting copiously and the latter were quite dry. The extreme solubility and diffusibility of sugar render it necessary that the nectar should be well protected from rain, and various arrangements for this purpose are found in flowers—such as the mouth of the flower hanging downwards, cushions of hairs, papillæ, spurs, &c. In the flower of the primrose, if the limb of the corolla be covered with water, it will be found that none can penetrate down the corolla-tube to the nectar, on account of the peculiar character of the surface of the petals causing a capillary repulsion. Were there no such means of protection the sugar would speedily be diffused to parts of the flower where it would be accessible to insects without their being of any service in the way of cross-fertilisation. In the fuchsia, which is rich in nectar, it is to be observed that no nectar is formed before the flower opens, and the amount is greatest at the time when the anthers are ready to dehisce. This in all likelihood happens in other cases where it is more difficult, on account of the smallness of the flowers, to ascertain the conditions. In this flower it is remarkable that three-fourths of the saccharine matter is in the condition of cane or uninverted sugar. Possibly this, taken in connection with the fact that nectaries are not unfrequently aborted or degenerated organs, such as a petal or stamen, may throw some light on the question in dispute among physiologists, as to whether nectar should be regarded as a true secretion or simply as an excretion of effete matters from the vegetable cells. It has further a physiological interest, as throwing light on the share which the bee has in elaborating honey, since this substance contains no cane sugar, although on account of the acid reaction of the nectar the process of inversion possibly goes on spontaneously. The extensive character of the operations that would appear, from the foregoing considerations, to be performed by insects which collect honey, enables us to form some conception of the importance of this factor, and will help us to judge of the adequacy or efficiency of this cause, which biologists believe to have exercised in past time an important influence in modifying the size, form, and colour of flowers, as well as in determining the character of certain organs of the insects by which such flowers are frequented.

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6. *Notes on some Dimorphic Plants.* By ALEX. S. WILSON, *M.A.*, *B.Sc.*

This paper had reference to *Erythræa centaurium* and *Silene acaulis.* The author pointed out that the former plant was probably dimorphic, as it exhibited heterostyly and had two kinds of pollen grains, in these respects closely resembling the primrose and bog-bean, as well as several others belonging to the order *Gentianaceæ,* of which it is a member. *Silene acaulis* was shown to have three kinds of flowers, male, female, and hermaphrodite, thus resembling *S. inflata,* which Axel has shown to be triœciously polygamous.

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7. *Some Mechanical Arrangements subserving Cross-fertilisation of Plants by Insects.* By ALEX. S. WILSON, *M.A.*, *B.Sc.*

The plants considered were *Pinguicula vulgaris*, *Vinca minor*, and the fox-glove. In *Vinca* the curiously shaped stigma resembles the stopper of a glass bottle. The circumference of its lower disc secretes a viscid substance which serves to smear the pollen so as to cause it to adhere to insects, thus resembling physiologically the sticky disc of the common orchid. The filaments of the stamens present a curious geniculate bend close to their insertion on the corolla, which acts as a lever when depressed, lowering the anther with its pollen into contact with the viscid matter on the lower part of the stigma. Somewhat similarly a peculiar bend on the filaments of the two stamens of *Pinguicula,* when pressed, causes the anthers to descend so as to impinge on an insect entering the flower, this latch-like mechanism dislodging the pollen from behind the under lip of the semi-petaloid stigma. The remarkable twists and curvings of the filaments of the fox-glove appear to act in a manner exactly analogous, for an insect pressing on their upturned edges as it passes over the floor of the flower must cause a shower of pollen to fall on its back from the overhanging anthers, on account of the disturbance produced by this lever-like mechanism.

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8. *On the Stipules of Spergularia Marina.* By ALEXANDER DICKSON, *M.D.*, *Regius Professor of Botany in the University of Glasgow.*

The stipules of this plant exhibit a peculiarity, which, if observed at all by descriptive botanists, has not received the attention it deserves on account of its remarkable character. The stipules are free from the petioles, and are wholly cellular in structure. From connation of those of opposite leaves they form "interpetiolar stipules," with more or less regularly, though slightly, bifid extremities. Lastly (and this is the important point), these stipules are united to each other round the backs of the petioles, so that a sheath is formed completely surrounding the axis and the two leaf-bases. This connation of stipules round the backs of the petioles is very interesting, as being a rare phenomenon. Cases are not uncommon where the two stipules are connate on the inner side of the leaf-base, constituting the so-called "axillary stipule," *e.g.*, *Potamogeton lucens*, &c., or on the opposite side of the axis from the leaf, *e.g.*, *Ficus elastica, Ricinus, Astragalus alpinus*, &c., constituting the so-called "oppositifoliar stipule;" but the only reference to connation of stipules behind or outside the leaf-base the author has been able to find, is to the case of certain species of *Astragalus* by St. Hilaire in his 'Morphologie.' In those species of *Astragalus* examined by the author he did not meet with any where the stipules are actually connate in this way; but in some, *e.g.*, *A. alopecuroides*, the bases of the stipules extend round the back of the leaf-stalk till they meet—a condition just short of connation. In the stipules of *Spergularia*, as we have seen, there is the interesting combination of the interpetiolar connation, with connation round the back of the leaf. In "English Botany" the condition is fairly enough represented by the artist, but the morphological peculiarity does not hitherto seem to have impressed itself upon the botanical mind.

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9. *On the Inflorescence of Senebiera didyma. By* ALEXANDER DICKSON, *M.D., Regius Professor of Botany in the University of Glasgow.*

The inflorescence here, like that of the mass of Cruciferous plants, is racemose. The racemes are "oppositifoliar," and at first sight the arrangement seems to be analogous to that of the oppositifoliar inflorescences of *Vitis* or of *Alchemilla arvensis,* where the inflorescence is really terminal, but is thrown to the side by a preponderant development of a "usurping shoot," the axillary bud of the last leaf produced by the primary axis before ending in the inflorescence; and it is to be noted that, of all the foliage leaves, that opposite the raceme is the only one apparently destitute of an axillary bud, which on the supposition would be represented by the "usurping shoot." If, however, the plant is more closely examined, a very remarkable condition is disclosed—one, indeed, which offers a morphological problem of considerable difficulty, and which probably can be effectually solved only by developmental study. The peculiarity consists in the constant occurrence of a solitary flower springing somewhere from the internode below the raceme, either about half-way down towards, or almost close to, the level of the leaf below. So far as observed, the solitary flower is never quite so low as the level of the lower leaf. Probably the first idea which would occur to one would be that this is a peculiar case of adhesion of parts; it might be supposed that from almost immediately above the second last leaf of the main axis, the bases of the terminal raceme, of the "usurping shoot," and of the axillant leaf of that shoot, had all become fused together. Now, although cases are known, on the one hand, of adhesion between the base of a terminal flower and that of the "usurping shoot" (*e.g., Helianthemum vulgare*), and on the other hand between the base of an axillant leaf and that of the usurping shoot in its axil (*e.g., Sedum* sp.), we do not know of connation of all three together. It is possible, but not probable. The view which seems to the author most fully to satisfy the conditions of this remarkable case may be stated briefly in categorical form as follows:—

1st. The racemose inflorescence is terminal, and properly begins just above the level of the "second-last" leaf. It would thus include the aforesaid solitary flower.

2nd. The raceme, after producing one ebracteate flower, produces at its second node a foliage-leaf, from whose axil the "usurping shoot" springs.

By such an explanation we can dispense with any cumbrous adhesion-hypothesis such as that indicated above. The peculiarity is that the main axis does not *per saltum* pass from the condition of a leafy axis to that of an axis of inflorescence, but begins by producing one flower and then developing a foliage-leaf, beyond which the series of flowers is uninterrupted. The "usurping shoot," as above indicated, represents the axillary bud of the foliage-leaf by which the raceme is interrupted.

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10. *On the Six-celled Glands of Cephalotus, and their similarity to the Glands of Sarracenia purpurea. By* ALEXANDER DICKSON, *M.D., Regius Professor of Botany in the University of Glasgow.*

The author pointed out that the peculiar six-celled glands found on the outer surface of the pitcher, both surfaces of the pitcher-lid, and both surfaces of the foliage-leaf of *Cephalotus,* are very nearly identical in structure with the glands on both inner and outer surfaces of the pitcher of *Sarracenia purpurea,* which were originally described by August Vogl. The author suggested that the remarkable resemblance in this respect, taken in connection with certain correspondences in the details of the insect-trapping apparatus, might indicate an affinity not hitherto suspected.

11. *Exhibition of Specimens of Isoetes echinospora. By* ALEXANDER DICKSON, *M.D., Regius Professor of Botany in the University of Glasgow.*

Dr. Dickson exhibited specimens referable to this species which he had lately found growing on muddy bottom, among *Potamogeton*, in about two feet of water in Loch Callater, Aberdeenshire. The plants were remarkable for the very slender and tapering character of the leaves, which curve outwardly. The macrospores are very markedly echinate, and in diameter about one-fourth smaller than those of *Isoetes lacustris.*

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12. *Some rare Scottish Alpine Plants. By* Dr. J. BAYLEY BALFOUR.

Specimens of some peculiar form of Scottish Alpine plants were exhibited—chiefly willows, sedges, and hawkweeds.

Of the willows, the most interesting was Sadler's willow (*Salix Sadleri*, Syme). This plant was discovered in 1874 by Mr. Sadler, on the rocks at the head of Loch Kander, Aberdeenshire. Since that date it has never been collected. In August of the present year Mr. Sadler, revisiting Loch Kander, found it in fair abundance, the specimens exhibited being of his gathering.

Of the other plants that were worthy of notice was *Carex frigida*, All. This sedge—a novelty in the British flora—was found by Mr. Sadler, in 1874, near the spot where he discovered *Salix Sadlerii*, Syme. Since then it has not been gathered, until this year Mr. Sadler again obtained some good specimens at the original locality. The chief interest in this plant centres in its being a rare instance of a non-Scandinavian plant inhabiting the Scottish Alps.

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13. *Notes on Naiudaceæ. By* Dr. J. BAYLEY BALFOUR.

TUESDAY, AUGUST 20, 1878.

The following Papers were read :—

1. *The Vertebrata of the Permian Formation of Texas.* *By* Professor EDWARD D. COPE, *F.S.A.*

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2. *Note on the Genus Holopus.* *By* Sir WYVILLE THOMSON.

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3. *Note on some Deep Sea Radiolarians.* *By* Sir WYVILLE THOMSON.

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4. *On the genus Ctenodus (Agassiz).* *By* Dr. R. H. TRAQUAIR.

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5. *The Mammoth in Siberia.* *By* HENRY H. HOWORTH, *F.S.A.*

The existence of the carcases of mammoths and rhinoceroses in Siberia, with their flesh and other soft parts intact, presents a problem which has not been hitherto satisfactorily solved. There are two theories current as to the means by which they came there. One is that they were floated down the great Siberian rivers from more tropical countries, and the other that they lived where their remains are now found. The former has now few adherents save perhaps Middendorf. The nature of the rivers; the fact that it would be impossible for such masses of flesh to float down them for hundreds of miles without being broken to pieces; the fact that they are found standing upright, that we have specimens of the remains of their food and the outward woolly covering of their bodies, are a few of the facts which conclusively show that they were not floated down the rivers. The remaining alternative which is now almost universally held, that they lived where their remains are found, necessitates another postulate, however. It is quite clear that neither elephant nor rhinoceros could live under the conditions which now prevail on the tundras bordering the Arctic Ocean; the terrible climate, the absence of trees and the universal covering of snow for a large part of the year makes it clear, *à priori*, that there must have been a change of climate in Siberia since they lived, and this is largely supported by the existence of traces of woods, and remains of a more southern vegetation, far to the north of the present limit of trees; and it seems clear that a temperate climate prevailed all over Siberia when the mammoths lived there. But there is another difficulty, which, so far as the author knew, has not hitherto been noticed. The fact of the flesh of these animals having been preserved intact, proves that they must have been frozen immediately after death, and remained frozen ever since. If the ground had thawed even during one summer, they would have decayed and been dissipated. Again, as they were buried in earth and mud, it is clear that when so buried the ground must have been soft. It is impossible to conceive of large masses of flesh being pushed underground if the earth was frozen fast, as it is over all Northern Siberia, from two feet below the surface. It follows, therefore, that the change of climate was sudden, was in fact in the nature of a catastrophe; and this is supported by the fact of the mammoths

and their associated companions being found in such hecatombs, while, as is familiar to travellers, the remains of modern elephants which have died in the forests are seldom found. This accounts also largely for the flesh of the huge beasts not having been torn and eaten by their carnivorous contemporaries. This conclusion seems at issue with much modern geological speculation, which rather shrinks from postulating catastrophes, but it nevertheless appears to be inevitable.

6. *Recent Additions to the List of Irish Lepidoptera.* *By* R. W. SINCLAIR.

7. *A Wryneck obtained in Ireland was exhibited by* A. E. JACOB.

8. *Germinating specimens of Cardamine pratensis were exhibited by* Dr. JOHN PRICE.

DEPARTMENT OF ANTHROPOLOGY.

CHAIRMAN OF THE DEPARTMENT—Professor Huxley, PH.D., LL.D., SEC. R.S., F.G.S.

THURSDAY, AUGUST 15, 1878.

The Department did not meet.

FRIDAY, AUGUST 16, 1878.

Professor HUXLEY gave the following Address:—

WHEN I undertook, with the greatest possible pleasure, to act as a lieutenant of my friend the President of this Section, I steadfastly purposed to confine myself to the modest and useful duties of that position. For reasons, with which it is not worth while to trouble you, I did not propose to follow the custom which has grown up in the Association of delivering an address upon the occasion of taking the chair of a section or department. In clear memory of the admirable addresses which you have had the privilege of hearing from Professor Flower, and just now from Dr. McDonnell, I cannot doubt that that practice is a very good one; though I would venture to say, to use a term of philosophy, that it looks very much better from an objective than from a subjective point of view. But I found that my resolution, like a great many good resolutions that I have made in the course of my life, came to very little, and that it was thought desirable that I should address you in some way. But I must beg of you to understand that this is no formal address. I have simply announced it as a few introductory remarks, and I must ask you to forgive whatever of crudity and imperfection there may be in the mode of expression of what I have to say, although naturally I shall do my best to take care that there is neither crudity nor inaccuracy in the substance of it. It has occurred to me that I might address myself to a point in connection with the business of this department which forces itself more or less upon the attention of everybody, and which, unless the bellicose instincts of human nature are less marked on this side of St. George's Channel than on the other, may possibly have something to do with the large audiences we are always accustomed to see in the Anthropological Department. In the Geological Section I have no doubt it will be pointed out to you, or, at any rate, such knowledge may crop up incidentally, that there are on the earth's surface what are called *loci* of disturbance, where, for long ages, cataclysms and outbursts of lava and the like take place. Then everything subsides into quietude; but a similar disturbance is set up elsewhere. In Antrim, at the middle of the tertiary epoch, there was such a great centre of physical disturbance. We all know that at the present time the earth's crust, at any rate, is quiet in Antrim, while the great centres of local disturbance are in Sicily, in Southern Italy, in the Andes, and elsewhere. My experience of the British Association does not extend quite over a geological epoch, but it does go back rather longer than I care to think about; and when I first knew the British Association, the *locus* of disturbance in it was the Geological Section. All sorts of terrible things about the antiquity of the earth,

and I know not what else, were being said there, which gave rise to terrible apprehensions. The whole world, it was thought, was coming to an end, just as I have no doubt that, if there were any human inhabitants of Antrim in the middle of the tertiary epoch, when those great lava streams burst out, they would not have had the smallest question that the whole universe was going to pieces. Well, the universe has not gone to pieces. Antrim is, geologically speaking, a very quiet place now, as well cultivated a place as one need see, and yielding abundance of excellent produce: and so, if we turn to the Geological Section, nothing can be milder than the proceedings of that admirable body. All the difficulties that they seemed to have encountered at first have died away, and statements that were the horrible paradoxes of that generation are now the commonplaces of schoolboys. At present the *locus* of disturbance is to be found in the Biological Section, and more particularly in the anthropological department of that Section. History repeats itself, and precisely the same apprehensions which were expressed by the aborigines of the Geological Section, in long far back time, are at present expressed by those who attend our deliberations. The world is coming to an end, the basis of morality is being shaken, and I don't know what is not to happen if certain conclusions which appear probable are to be verified. Well, now, whoever may be here thirty years hence—I certainly shall not be—but, depend upon it, whoever may be speaking at the meeting of this department of the British Association thirty years hence will find, exactly as the members of the Geological Section have found, on looking back thirty years, that the very paradoxes and horrible conclusions, things that are now thought to be going to shake the foundations of the world, will by that time have become parts of every-day knowledge and will be taught in our schools as accepted truth, and nobody will be one whit the worse.

The considerations which I think it desirable to put before you, in order to show the foundations of this conviction at which I have very confidently arrived, are of two kinds. The first is a reason based entirely upon philosophical considerations, namely, this—that the region of pure physical science, and the region of those questions which specially interest ordinary humanity, are apart, and that the conclusions reached in the one have no direct effect in the other. If you acquaint yourself with the history of philosophy, and with the endless variations of human opinion therein recorded, you will find that there is not a single one of those speculative difficulties which at the present time torment many minds as being the direct product of scientific thought, which is not as old as the times of Greek philosophy, and which did not then exist as strongly and as clearly as such difficulties exist now, though they arose out of arguments based upon merely philosophical ideas. Whoever admits these two things—as everybody who looks about him must do—whoever takes into account the existence of evil in this world and the law of causation—has before him all the difficulties that can be raised by any form of scientific speculation. And these two difficulties have been occupying the minds of men ever since man began to think. The other consideration I have to put before you is that, whatever may be the results at which physical science as applied to man shall arrive, those results are inevitable—I mean that they arise out of the necessary progress of scientific thought as applied to man. You all, I hope, had the opportunity of hearing the excellent address which was given by our President yesterday, in which he traced out the marvellous progress of our knowledge of the higher animals which has been effected since the time of Linnæus. It is no exaggeration to say that at this present time the merest tyro knows a thousand times as much on the subject as is contained in the work of Linnæus, which was then the standard authority. Now how has that been brought about? If you consider what zoology, or the study of animals, signifies, you will see that it means an endeavour to ascertain all that can be studied, all the answers that can be given respecting any animal under four possible points of view. The first of these embraces considerations of structure. An animal has a certain structure and a certain mode of development, which means that it passes through a series of stages to that structure. In the second place, every animal exhibits a great number of active powers, the knowledge of which constitutes its physiology; and under those active powers we have, as physiologists, not only to include such matters as have been referred to by Dr. M'Donnell in his observations, but to take into account other kinds of activity. I see it announced that the Zoological

Section of to-day is to have a highly interesting paper by Sir John Lubbock on the habits of ants. Ants have a polity, and exhibit a certain amount of intelligence, and all these matters are proper subjects for the study of the zoologist as far as he deals with the ant. There is yet a third point of view in which you may regard every animal. It has a distribution. Not only is it to be found somewhere on the earth's surface, but palæontology tells us, if we go back in time, that the great majority of animals have had a past history—that they occurred in epochs of the world's history far removed from the present. And when we have acquired all that knowledge which we may enumerate under the heads of anatomy, physiology, and distribution, there remains still the problem of problems to the zoologist, which is the study of the causes of those phenomena, in order that we may know how they came about. All these different forms of knowledge and inquiry are legitimate subjects for science, there being no subject which is an illegitimate subject for scientific inquiry, except such as involves a contradiction in terms, or is itself absurd. Indeed, I don't know that I ought to go quite so far as this at present, for undoubtedly there are many benighted persons who have been in the habit of calling by no less hard names conceptions which the President of this Meeting tells us must be regarded with much respect. If we have four dimensions of space we may have forty dimensions, and that would be a long way beyond that which is conceivable by ordinary powers of imagination. I should, therefore, not like to draw too closely the limits as to what may be contradiction to the best-established principles. Now, let us turn to a proposition which no one can possibly deny—namely, that there is a distinct sense in which man is an animal. There is not the smallest doubt of that proposition. If anybody entertains a misgiving on that point he has simply to walk through the museum close by, in order to see that man has a structure and a framework which may be compared, point for point and bone for bone, with those of the lower animals. There is not the smallest doubt moreover that, as to the manner of his becoming, man is developed, step by step, in exactly the same way as they are. There is not the smallest doubt that his activities—not only his mere bodily functions, but his other functions—are just as much the subjects of scientific study as are those of ants or bees. What we call the phenomena of intelligence, for example (as to what else there may be in them, the anthropologist makes no assertion)—are phenomena following a definite casual order just as capable of scientific examination, and of being reduced to definite law, as are all those phenomena which we call physical. Just as ants form a polity and a social state, and just as these are the proper and legitimate study of the zoologist, so far as he deals with ants; so do men organise themselves into a social state. And though the province of politics is of course outside that of anthropology, yet the consideration of man, so far as his instincts lead him to construct a social economy, is a legitimate and proper part of anthropology, precisely in the same way as the study of the social state of ants is a legitimate object of zoology. So with regard to other and more subtle phenomena. It has often been disputed whether in animals there is any trace of the religious sentiment. That is a legitimate subject of dispute and of inquiry; and if it were possible for my friend Sir John Lubbock to point out to you that ants manifest such sentiments he would have made a very great and interesting discovery, and no one could doubt that the ascertainment of such a fact was completely within the province of zoology. Anthropology has nothing to do with the truth or falsehood of religion—it holds itself absolutely and entirely aloof from such questions—but the natural history of religion, and the origin and the growth of the religions entertained by the different kinds of the human race, are within its proper and legitimate province. I now go a step farther, and pass to the distribution of man. Here, of course, the anthropologist is in his special region. He endeavours to ascertain how various modifications of the human stock are arranged upon the earth's surface. He looks back to the past, and inquires how far the remains of man can be traced. It is just as legitimate to ascertain how far the human race goes back in time as it is to ascertain how far the horse goes back in time; the kind of evidence that is good in the one case is good in the other; and the conclusions that are forced on us in the one case are forced on us in the other also. Finally, we come to the question of the causes of all these phenomena, which, if permissible in the case of other animals, is permissible in the animal man. Whatever evidence, whatever chain of reasoning justifies us in concluding that the horse,

for example, has come into existence in a certain fashion in time, the same evidence and the same canons of logic justify us to precisely the same extent in drawing the same kind of conclusions with regard to man. And it is the business of the anthropologist to be as severe in his criticism of those matters in respect to the origin of man as it is the business of the palæontologist to be strict in regard to the origin of the horse; but for the scientific man there is neither more nor less reason for dealing critically with the one case than with the other. Whatever evidence is satisfactory in one case is satisfactory in the other; and if any one should travel outside the lines of scientific evidence, and endeavour either to support or oppose conclusions which are based upon distinctly scientific grounds, by considerations which are not in any way based upon scientific logic or scientific truth—whether that mode of advocacy was in favour of a given position, or whether it was against it, I, occupying the chair of the Section, should, most undoubtedly, feel myself called upon to call him to order, and to tell him that he was introducing topics with which we had no concern whatever.

I have occupied your attention for a considerable time; yet there is still one other point respecting which I should like to say a few words, because some very striking reflections arise out of it. The British Association met in Dublin twenty-one years ago, and I have taken the pains to look up what was done in regard to our subject at that period. At that time there was no Anthropological Department. That study had not yet differentiated itself from zoology, or anatomy, or physiology, so as to claim for itself a distinct place. Moreover, without reverting needlessly to the remarks which I placed before you some time ago, it was a very volcanic subject, and people rather liked to leave it alone. It was not until a long time subsequently that the present organisation of this section of the Association was brought about; but it is a curious fact, that although truly anthropological subjects were at the time brought before the Geographical Section—with the proper subject of which they had nothing whatever to do—I find, that even then, more than half of the papers that were brought before that section were, more or less distinctly, of an anthropological cast. It is very curious to observe what that cast was. We had systems of language—we had descriptions of savage races—we had the great question, as it then was thought, of the unity or multiplicity of the human species. These were just touched upon, but there was not an allusion in the whole of the proceedings of the Association, at that time, to those questions which are now to be regarded as the burning questions of anthropology. The whole tendency in the present direction was given by the publication of a single book, and that not a very large one—namely, 'The Origin of Species.' It was only subsequent to the publication of the ideas contained in that book that one of the most powerful instruments for the advance of anthropological knowledge—namely, the Anthropological Society of Paris—was founded. Afterwards the Anthropological Institute of this country and the great Anthropological Society of Berlin came into existence, until it may be said that, at the present time, there is not a branch of science which is represented by a larger or more active body of workers than the science of anthropology. But the whole of these workers are engaged, more or less intentionally, in providing the data for attacking the ultimate great problem, whether the ideas which Darwin has put forward in regard to the animal world are capable of being applied in the same sense and to the same extent to man.

That question, I need not say, is not answered. It is a vast and difficult question, and one for which a complete answer may possibly be looked for in the next century; but the method of inquiry is understood; and the mode in which the materials bearing on that inquiry are now being accumulated, the processes by which results are now obtained, and the observation of new phenomena lead to the belief that the problem also, some day or other, will be solved. In what sense I cannot tell you. I have my own notion about it, but the question for the future is the attainment, by scientific processes and methods, of the solution of that question. If you ask me what has been done within the last twenty-one years towards this object, or rather towards clearing the ground in the direction of obtaining a solution, I don't know that I could lay my hand upon much of a very definite character—except as to methods of investigation—save in regard to one point. I have some reason to know that about the year 1860, at any rate, there

was nothing more volcanic, more shocking, more subversive of everything right and proper, than to put forward the proposition that as far as physical organisation is concerned there is less difference between man and the highest apes than there is between the highest apes and the lowest. My memory carries me back sufficiently to remind me that, in 1860, that question was not a pleasant one to handle. The other day I was reading a recently-published valuable and interesting work, 'L'Espèce Humaine,' by a very eminent man, M. de Quatrefages. He is a gentleman who has made these questions his special study, and has written a great deal and very well about them. He has always maintained a temperate and fair position, and has been the opponent of evolutionary ideas, so that I turned with some interest to his work as giving me a record of what I could look on as the progress of opinion during the last twenty years. If he has any bias at all, it is one in the opposite direction to that in which my own studies would lead me. I cannot quote his words, for I have not the book with me, but the substance of them is that the proposition which I have just put before you is one the truth of which no rational person acquainted with the facts could dispute. Such is the difference which twenty years has made in that respect, and speaking in the presence of a great number of anatomists, who are quite able to decide a question of this kind, I believe that the opinion of M. de Quatrefages on the subject is one they will all be prepared to endorse. Well, it is a comfort to have got that much out of the way. The second direction in which I think great progress has been made is with respect to the processes of anthropometry, in other words, in the modes of obtaining those data which are necessary for anthropologists to reason upon. Like all other persons who have to deal with physical science, we confine ourselves to matters which can be ascertained with precision, and nothing is more remarkable than the exactness which has been introduced into the mode of ascertaining the physical qualities of man within the last twenty-five years. One cannot mention the name of Broca without the greatest gratitude; and I am quite sure that, when Professor Flower brings forward his paper on cranial measurements on Monday next, you will be surprised to see what precision of method and what accuracy are now introduced, compared with what existed twenty-five years ago, into these methods of determining the facts of man's structure. If, further, we turn to those physiological matters bearing on anthropology which have been the subject of inquiry within the last score of years, we find that there has been a vast amount of progress. I would refer you to the very remarkable collection of the data of sociology by Mr. Herbert Spencer, which contains a mass of information useful on one side or the other, in getting towards the truth. Then I would refer you to the highly interesting contributions which have been made by Professor Max Muller and by Mr. Tylor to the natural history of religions, which is one of the most interesting chapters of anthropology. In regard to another very important topic, the development of art and the use of tools and weapons, most remarkable contributions have been made by General Lane Fox, whose museum at Bethnal Green is one of the most extraordinary exemplifications that I know of the ingenuity, and, at the same time, of the stupidity of the human race. Their ingenuity appears in their invention of a given pattern or form of weapon, and their profound stupidity in this, that having done so, they kept in the old grooves, and were thus prevented from getting beyond the primitive type of these objects and of their ornamentation. One of the most singular things in that museum is the exemplification of the wonderful tendency of the human mind when once it has got into a groove to stick there. The great object of scientific investigation is to run counter to that tendency.

Great progress has been made in the last twenty years in the direction of the discovery of the indications of man in a fossil state. My memory goes back to the time when anybody who broached the notion of the existence of fossil man would have been simply laughed at. It was held to be a canon of palæontology that man could not exist in a fossil state. I don't know why, but it was so; and that fixed idea acted so strongly on men's minds that they shut their eyes to the plainest possible evidence. Within the last twenty years we have an astonishing accumulation of evidence of the existence of man in ages antecedent to those of which we have any historical record. What the actual date of those times was,

and what their relation is to our known historical epochs, I don't think anybody is in a position to say. But it is beyond all question that man, and not only man, but what is more to the purpose, intelligent man, existed at times when the whole physical conformation of the country was totally different from that which characterises it now. Whether the evidence we now possess justifies us in going back further or not, that we can get back as far as the epoch of the drift is, I think, beyond any rational doubt; that may be regarded as something settled. But when it comes to a question as to the evidence of tracing back man further than that—and recollect the drift is only the scum of the earth's surface—I must confess that, to my mind, the evidence is of a very dubious character.

Finally, we come to the very interesting question—as to whether, with such evidence of the existence of man in those times as we have before us, it is possible to trace in that brief history any evidence of the gradual modification from a human type somewhat different from that which now exists to that which is met with at present. I must confess that my opinion remains exactly what it was some eighteen years ago, when I published a little book which I was very sorry to hear my friend, Professor Flower, allude to yesterday, because I had hoped that it would have been forgotten amongst the greater scandals of subsequent times. I did there put forward the opinion that what is known as the Neanderthal skull is, of human remains, that which presents the most marked and definite characteristics of a lower type—using the language in the same sense as we would use it in other branches of zoology. I believe it to belong to the lowest form of human being of which we have any knowledge, and we know from the remains accompanying that human being, that as far as all fundamental points of structure were concerned, he was as much a man—could wear boots just as easily—as any of us, so that I think the question remains pretty much where it was. I don't know that there is any reason for doubting that the men who existed at that day were in all essential respects similar to the men who exist now. But I must point out to you that this conviction is by no means inconsistent with the doctrine of evolution. The horse, which existed at that time, was in all essential respects identical with the horse which exists now. But we happen to know that going back further in time the horse presents us with a series of modifications by which it can be traced back from an earlier type. Therefore it must be deemed possible that man is in the same position, although the facts we have before us with respect to him tell in neither one way nor the other. I have now nothing more to do than to thank you for the great kindness and attention with which you have listened to these informal remarks.

The following Papers were read:—

1. *Notes on the Prehistoric Monuments of Cornwall as compared with those in Ireland. By* Miss A. W. BUCKLAND.

The prehistoric monuments of Cornwall, believed by archæologists to be the work of the same race as those of Ireland, present, in the midst of strong resemblance, certain points of difference, which deserve the attention not only of archæologists but of ethnologists. In both countries they consist of tumuli, including chambered barrows and giants' graves—monoliths or menhirs, circles, cromlechs or dolmens, and holed-stones, all probably sepulchral; and hut-circles, cliff-castles, curious caves and crosses, whilst in Ireland we find in addition earthworks called raths and round towers. Long barrows, which are looked upon as the most ancient of burial places, belonging to the stone age, are wanting in both countries, hence we may infer that the people who erected them in England and Scotland never inhabited Cornwall and Ireland, where the earliest barrows seem to belong to the Bronze age, the mode of interment in Cornwall being chiefly by cremation; but these tumuli may not represent the earliest tombs in these countries. Sir William Wilde believes that the earliest premetallic Irish were the erectors of gigantic cromlechs covered with earth, whilst the menhirs in both countries are very ancient memorials of the dead, although not always covering a grave, the "Pipers" in Cornwall being of the latter class. Some of these menhirs were afterwards converted to Christian uses, whilst some in Ireland bear Ogham inscriptions. The circles in Cornwall are

small as compared to those of Stonehenge and Avebury. Nine exist in the extreme West of Cornwall, but no avenues are traceable in connection with them, the same fact having been observed of some of the Irish examples; the Cornish consist generally of nineteen stones. The cromlechs of Cornwall are of the free-standing order, but seem to follow no special rule as to the number of stones composing them. The chambered tumuli and giants' graves do not equal in size the great pyramids of Dowth and New Grange, although of the same general construction. The holed stones of Cornwall, which vary greatly in form and size, have their counterparts in Ireland, Scotland, and France, but the men-an-tol seems unique; their use is unknown, but in Cornwall and in Ireland they have a reputation as healing agents. From the difference in shape and size they could hardly have served as doors to dolmens, like the Indian examples, but probably were associated with the God of Healing. Of non-sepulchral monuments the beehive huts form an important part. Several groups exist in Cornwall, apparently identical with the Irish cloughans in Kerry and Arran. The Cornish cliff-castles and Irish raths are both ascribed to the Danes, but they differ essentially in construction, the Irish rath consisting of earthwork only, whilst the Cornish cliff-castles are three or four circles of uncemented stones heaped together to form walls. The crosses of Cornwall, with few exceptions, seem older and ruder than those of Ireland, and bear no inscriptions in Ogham, although there are on some hieroglyphic markings, but it is noteworthy that the Irish round towers do not appear in Cornwall, although traditions of Irish saints are numerous there. All these monuments are generally ascribed to the Celts, but this is probably an error, since maps showing the distribution of these remains prove that in most countries they follow certain lines, indicating the migrations of different tribes or races. The great cromlechs of Ireland are found chiefly on the coast, and similar groupings occur in almost every country, so that a map of the world wherein these are clearly marked would be a great boon to ethnologists. Two distinct types of skull, the one dolicocephalic, the other brachycephalic, are found associated with the Irish remains, and although both are assumed to be Celtic, the term seems inapplicable to *both*. The constructors of similar monuments in India belong to the dark-skinned pre-Aryan stock. Attention to the distribution, position with regard to the cardinal points, and the number of stones forming these monuments, is of considerable importance, and also their constant occurrence in bog or waste land. Their position appears to the author to have some connection with the point from which their builders first emigrated, and the rude hieroglyphs on some, to denote the tribal marks or totems of deceased chiefs.

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2. *Flint Factories at Portstewart and elsewhere in the North of Ireland.* *By* W. J. Knowles.

Since this subject was brought forward at the Glasgow meeting there have been found at Portstewart, besides additional flint implements and beads, some lumps of porous lava, of the nature of pumice, and a few small flakes of obsidian. The lava is rounded by waterwearing and floats on water, and the flakes or chips of obsidian have bulbs of percussion. It is supposed that these substances are not native productions, but that the lava, with obsidian attached, may have been carried by currents from a distance, and cast ashore at Portstewart.

Sandhills near Castlerock, County Londonderry, and at Whitepark Bay, near Ballintoy, were examined, and similar objects to those found at Portstewart were obtained. At Whitepark Bay, which was the richer of the two, many hundreds of flint implements were found, together with an oval toolstone, bone pins, bored and cut bones, hammer-stones, cores, flakes, broken pottery, broken and split bones, teeth, and shells. Blackish layers representing the ancient surface are to be seen like those at Portstewart. The layers vary from about three to twelve inches in thickness, and the objects are found imbedded in them, except where they are set free by denudation. Twenty or thirty feet of sand protected by close vegetation rests on the layers on some places, while in others the covering is removed, but the layer which is pretty solid and coherent has resisted the action of the wind and still remains.

The animal remains as determined by Professor A. Leith Adams, F.R.S., were found to contain those of man, horse, ox, dog or wolf, fox, deer, and hog.

Flint factories are also found at Larne and other places round the coast. Some are also found inland at a distance from the places where a supply of flint could be obtained. In one of these inland places on the banks of the Bann, near Portglenone, several flint implements were found approaching the form known as palæolithic—all having a thick base for holding in the hand and a cutting point—and it was thought strange that these, like the palæolithic implements of large size as mentioned in Evan's "Stone Implements," should be found mainly in connection with rivers.

Our best authorities believe that all the stone implements found in Ireland are of Neolithic age. It is not known that any extinct animal, such as the mammoth and Irish Elk, has been found asssociated with flint implements in Ireland, but the implements from the Bann were found in the diatomaceous deposit below the peat where remains of Irish Elk are usually found, and well-marked flakes have been found at considerable depths from the surface in the raised beach at Larne, and there is at present in possession of the Rev. Dr. Grainger, M.R.I.A., of Broughshane, County Antrim, a mammoth's tooth found near Larne.* These facts, it was thought, were sufficient at least to create a suspicion in our minds that some of the Irish stone implements might be found to be older than the Neolithic age.

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3. *The Prehistoric Sculptures of Ilkley, Yorkshire. By* J. ROMILLY ALLEN.

Ireland is a country rich in sculptures of the prehistoric period, and it is most important to science that the comparative method should be applied to this branch of research. The object in bringing the subject before the British Association at Dublin is to enable the Yorkshire examples here described to be compared with those found in Ireland. The particular type of sculpture dealt with in the following paper is known as "*cup-and-ring marking.*" Sculptures of this description were discovered in the North of England in 1825, and subsequently in Scotland, Ireland, Brittany, and Wales. The most valuable addition to the information already collected was made in 1877 by Mr. Rivett-Carnac, who found cup-and-ring marks, identical with the ones of this country, amongst the Kamáon Hills in India. The meaning of the symbols is fully understood by the natives, and is supposed to have reference to "*Lingam*" worship. Cup-and-ring marks in Great Britain are intimately connected with the burial rites, and therefore probably with the religious ceremonies of the ancient inhabitants of this country, since the symbols are frequently found carved on the stones of sepulchral circles and chambers, and on the cover stones of cinerary urns. A full investigation of the subject may be the means of throwing great light on the nature of the religion which preceded Christianity in this country. Examples of prehistoric sculpture from different localities should be carefully compared. The remnants of Paganism incorporated in the superstitions of remote districts and found mixed with the ceremonies of the Christian church should be critically examined. The most successful method of conducting such researches is to work steadily backward from the historic period to the prehistoric, tracing the gradual course of development to its source.

The remainder of the paper is devoted to a description of the magnificent group of cup-and-ring sculptures found on rocks in the neighbourhood of Ilkley, in Yorkshire.

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4. *Report of the Earth-works Committee; being an account of Excavations in Cæsar's Camp, Folkestone.*—Major-General Lane Fox, F.R.S., regrets that it has not been possible to complete this report in time for the present volume.

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5 *On Excavations at Mount Caburn, Lewes, Sussex. By* Major-General LANE FOX, F.R.S.

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* See Dr. Grainger's paper, Transactions of Sections, 1874. p. 73.

SATURDAY, AUGUST 17, 1878.

This Department did not meet.

MONDAY, AUGUST 19, 1878.

The following Papers were read:—

1. *Methods and Results of Measurements of the Capacity of Human Crania.* *By* William Henry Flower, *F.R.S.*

The capacity of the cavity of the cranium is one of its most important measurements, and at the same time one of the most difficult to ascertain. The results of about three thousand experiments were given in this communication. Two methods had been chiefly employed—1. That of Broca, as described in his memoir *Sur la Mensuration de la Capacité du Crane*, Mém. de la Société d'Anthropologie, T. 1er (2e Série), Paris 1873; the material used being leaden shot. 2. That of Busk, "Note on a ready method of measuring the capacity of skulls," "Journ. Anthrop. Inst.," vol. iii. p. 200. In both the author has had the advantage of the personal explanations and instructions of their respective inventors. When these two methods were used to measure the same skulls, the author found that the first invariably gave a larger capacity than the second, amounting generally to as much as 3 or 4 cubic inches. To ascertain which, or whether, either was absolutely correct, test skulls, prepared by stopping the larger apertures with wax, and impregnating the bone tissue with melted paraffin to make it impervious to fluids were employed. In these the capacity could be ascertained with exactness by means either of mercury or water. In a skull so prepared, Broca's method of mensuration gave 70 cubic centimetres above the real capacity, Busk's 10 to 15. A slight modification of the last, using mustard seed, and taking every care to fill both the cranium and the choremometer to the utmost by repeated shakings, gave very accurate results. The details of the method (which cannot be described in an abstract) were demonstrated to the audience.

The results of the measurement of the collection of about a thousand crania in the Museum of the Royal College of Surgeons of England were then described, but their value as affording the data for comparing different races was not great, owing to the insufficient numbers of each race available for comparison, as all immature skulls, *i.e.* those in which the basal suture was not closed, were rejected in the averages, and the sexes were carefully separated. To ascertain the influence of sex, all the skulls of whatever race in the collection in which the sex is absolutely known from other evidence than that presented by the skull itself, were measured with the following result:—Sixty-three skulls of known males have an average of 1433 cubic centimetres. Twenty-four skulls of known females have an average of 1224 cubic centimetres, giving the proportion of 1000 to 854. The largest normal skull in the collection is 2075; it is that of an Englishman of unknown history; the smallest, a female Vedda, measures 960 cubic centimetres. The following are the averages of male skulls only, expressed in cubic centimetres, the numbers of the skulls measured being placed in brackets. The insufficiency of many of these will be obvious, but they may serve as approximations. With

regard to the higher races, especially the English, it must be noted that the skulls examined are those of the least intellectually developed portion of the community, while with some of the lower races, it may be rather the reverse. The general order in which the races are placed does not differ greatly from that of the tables of Barnard Davis and Broca; but the actual capacities are all smaller, especially than those of the latter author, owing to the difference of the method of measurement employed. West Coast of North America, mostly deformed (7), 1589; Lapps (4), 1569; Ancient Italian (11), 1558; Eskimo (17), 1546; Modern Greek (9), 1546; English (17), 1542; Guanches (6), 1498; Japanese (6), 1486; Kaffirs (7), 1485; Modern Italians (74), 1475; Ancient Egyptians (8), 1464: Polynesians (18), 1454: Malays (17), 1432; Chinese (16), 1424; African Negroes of various tribes (26), 1377; Peruvians (47), 1345; Melanesians (30), 1318; Tasmanians (6), 1309; Hindoos (23), 1306; Australians (26), 1285; Andamanese (4), 1220; Veddas (3), 1205.

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2. *Report of the Anthropometric Committee.*—See Reports, p. 152.

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3. *On a Colour Scale.* *By* E. W. Brabrook.

Having regard to Professor Broca's types of colour of eyes, hair, and skin adopted by the Association in their 'Notes and Queries on Anthropology,' and to the selection made from those types by the Anthropometric Committee, the writer drew attention to a very comprehensive scale of colours lately published by the Société Stenochromique of Paris, given to him by Dr. Paul Topinard, as affording a step towards universal scientific language on the matter. The scale comprises forty-two colours and about twenty shades of each, altogether more than 800 shades. The writer attempted to identify Broca's types of eye-colour with some of the shades of colours 4, 10, 12, 13, 18, 19, 33 and 34 in the scale: and his types of hair and skin colour with some of those of 3, 4, 5, 6, 32, 33, 34 and 35—showing that a comparatively limited range would suffice for all practical purposes in anthropology.

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4. *Left-handedness.* *By* Henry Muirhead, *M.D.*

The writer directed attention chiefly to the seeming hereditariness of left-handedness in some families instancing his own as one in which he had been unable to trace a single instance of left-handedness. Contrasted with this he gave statistics of a family (named White) in Cambuslang for a period of 123 years. Of the individuals of this family so far as accurately known thirty-four used the right hand and nine the left; nearly twenty-one per cent. Information as to the other members could not be relied on. Only one of the nine married and had children whose right and left-handedness was known (she had five children two of them left-handed) so that in the majority of the instances given the parent was not left-handed. In all cases measured by the writer, left-handed individuals have the left foot from one-third to one-eighth of an inch longer than the right. The converse of this is usual in right-handed people. Right-handed people in looking with one eye (the other being shut) use the right. All left-handed *females*, so far as hitherto scrutinized, use the left. Of left-handed males examined only two out of fourteen used the left eye.

5. *On the Evils arising from the use of Historical National Names as Scientific Terms.* By A. L. LEWIS.

The propositions endeavoured to be established by the author were: (1) That there were at the first population of Europe certain primitive races, (of which three were particularly described); (2) that these races are so mixed at the present day that representatives of them appear not only in most European nations, but in the same families, and among children of the same parents; (3) that notwithstanding this mixture, and the effects which it must permanently have, racial characters display an astonishing permanence; (4) that this mixture, being so slow in its effects, and yet having become so general, has probably been at work for a very great length of time, so great that the peoples to whom the earliest history of Europe introduces us were probably nearly as much mixed as those of the present day; (5) that it is desirable to discontinue the use of the political names of those peoples as ethnic names, and to employ others based on the physical characteristics of the individual; (6) that while physical characteristics are the only basis for a true division into races, yet in any practical application of this division the influence upon individuals of different races of a community of language, custom, history, or tradition must not be lost sight of, although these things do not prove community of race, but only the contact at some time or other of the races to whom they are now common.

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6. *On some American Illustrations of new Varieties of Man.* By Professor DANIEL WILSON, LL.D.

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7. *On the Courses of Migration and Commerce, traced by Art Relics and Religious Emblems.* By J. S. PHENÉ, *LL.D., F.S.A.*

In this paper references were first made to some remarkable sculptures of the oldest historical notice, existing in the mountains of Asia Minor, particularly the "Niobe" of Homer, on Mount Sipylus, and the Sesostris figure at Nymphio, and subsequently, to the various colossal and other rock-hewn sculptures in the Sporades and Cyclades, having affinity, by similarity of style, to those of Asia Minor.* It was then mentioned that according to Strabo, tradition showed that the religion of this part of Asia Minor was transferred to the south of Gaul, in the ancient city of Massilia, now Marseilles, and thence consequently it spread over the west of Europe. That this religion brought with it the idea of the colossal in representation, which probably accounts for the ancient colossal figures in Brittany and Britain, and the love for the colossal still found over the whole of that part of France lying between Marseilles and Brittany, the old route of tin traffic between Britain and the Mediterranean. Still existing Phœnician customs were referred to on the same route, and then references were made to some discoveries on this route, and in the south of Britain and the south of Ireland, which tended to the conclusion that the articles discovered were introduced by Oriental, probably by Phœnician traders. One of these was a sculptured human head in the exact style of Assyrian art, as found at Nineveh, and which was discovered some slight distance under the surface on the estate of the Earl of Mount Edgcumbe, in Devonshire, who had drawn the attention of the author of the paper to it, and furnished him with a photograph. Another was a bronze mask or head found in a bog in the south of Ireland, near the Galtee mountains; it was the property of Lord James Butler, by whom the particulars and a photograph were furnished to Dr. Phené with a request that he would give his attention to the matter, and throw what light he was able on the subject; and to which, in response to such request, the author had devoted much time and research. This bronze represented the head of a cow, and had a close resemblance to the head found by Dr. Schliemann at Mycenæ, which he identified as the head of Hera. The latter relic was minutely examined by Dr. Phené at Athens, every facility

being afforded him by the Greek Government. The Mycenæ head was silver, with horns thickly plated with gold, and the head found in Ireland was a bronze one, with the horns (missing) made to take on and off, thereby clearly indicating that they were capable of being removed for security, and were therefore, no doubt, also golden. Both the heads had the sun disc on the forehead, but the bronze one, which he considered was evidently of Phœnician workmanship, had also the emblem of Astarte or Ashtoreth, the Sidonian deity, on the forehead. In the mask found in Ireland, the tongue protruded, indicating sleep or rest, and this symbolism was further exemplified by the crescent moon being placed beneath the sun disc, and so indicative of her rest or sleep, a strong similitude when taken in connection with the well-known appeal to the priests of Baal, who must have represented their deities in action or occupation, "Cry aloud, for he is a god, either he is talking, or he is pursuing, or sleepeth, and must be awaked." Dr. Phené, who had gone carefully over the whole districts referred to in Asia Minor, Greece, the Levant, and the complete course in France, found a cow's head sculptured in the island of Paros, and another on part of an ancient temple now forming the lintel of a Greek church near Amyclæ, not far from Sparta. Another object of great interest was represented, as were all the others, by a fine photograph representing a bronze figure of a deity, shown to be the Tyrian Hercules, found at Vienne, near Besançon, not far from the old route referred to, through Gaul. This deity bore on its head an enormous crown composed of hammers, the number of which agrees with the united number of the Kabiri of Samothrace and the Cyclopes of Sicily, their occupation being the same, viz. that of metallurgists. Dr. Phené considers they represented the same personifications, but lost the attributes of divinity as their traditions were brought westward. The attitude of this deity and a vessel he holds in his right hand agree with the representation of one of the Kabiri on a coin of Pergamus.

TUESDAY, AUGUST 20, 1878.

The following Papers were read:—

1. *Les Races Anciennes de l'Irlande. Utilité de l'étude des traditions qui les concernent pour l'ethnographie de l'Europe primitive.* Par HENRI MARTIN.

J'ai désiré présenter à cette savante association quelques observations sur un sujet qui me semble digne d'intérêt et qui mériterait de plus amples développements; mais j'aurai atteint mon but si j'ai pu attirer l'attention de l'assistance sur la question qui me préoccupe: cette question, c'est la concordance que je crois trouver entre les résultats qu'obtiennent actuellement les recherches des anthropologistes et des ethnographes sur les vieilles populations du continent et les résultats que donne l'étude des traditions historiques et légendaires de l'Irlande.

Les anthropologistes signalent une race brune brachycéphale qui existe le long du Danube dans les régions où ont dominé jadis les Gaulois blonds dolicocéphales; on retrouve cette race brune en France, dans la Celtique de César (France centrale) et plus ou moins dans le reste de la France; on la retrouve aussi à des proportions diverses en Angleterre, Galles, Écosse, Irlande. On la retrouve partout mêlée aux Gaulois ou Celtes blonds ou châtains et aux yeux bleus. Ces hommes bruns étaient la race dominée: les grands Gaulois blonds de l'histoire grecque et romaine étaient la race dominante.

Examinons maintenant ce que nous donnent les traditions irlandaises.

L'Irlande semble d'abord occupée par des sauvages qui n'ont pas de nom dans l'histoire; puis arrivent successivement plusieurs essaims, plusieurs colonies de Celtes primitifs dont les établissements ne subsistent pas, mais dont le souvenir cependant persiste; leurs conducteurs supposés sont évidemment des personnages mythologiques, de vieilles divinités qu'on a transformées beaucoup plus tard en personnages humains. Un de ces noms importe à signaler: le nom de Némedh, et parce que Némedh est l'ancêtre supposé des colonies postérieures qui réussirent enfin à s'établir d'une manière durable en Irlande, et parce que ce nom de Némedh se retrouve partout dans les traditions des peuples celtiques, depuis l'Irlande jusque dans la Gaule d'Asie (Galatie): il désigne tout ce qui est ancien, vénérable, sacré: c'est le nom même des sanctuaires druidiques.

A la race de Némedh, suivant la tradition, appartient donc le premier peuple qui ait laissé des traces subsistantes en Irlande, le peuple des Fir-Bolgs. On a voulu en faire des Belges, mais ils n'ont pas le moindre rapport avec les Belges de César, qui sont les plus récents, en Occident, des grands Gaulois blonds. Les Fir-Bolgs sont au contraire très anciens, et ils sont une petite race brune. Comment alors la tradition en fait-elle une branche des descendants de Némedh, c'est-à-dire des Celtes ou Gaulois? C'est que, s'ils n'étaient pas de même sang, ils étaient de même langue et de mœurs analogues plus ou moins; ils étaient *celtisés* quand ils vinrent en Irlande; les noms d'hommes et de lieux qui proviennent d'eux sont des noms celtiques comme ceux des premières colonies et comme ceux des autres immigrations postérieures.

Cette observation relative aux Fir-Bolgs d'Irlande est également applicable aux Ligures de Gaule et d'Italie, ce peuple brun, mêlé aux Celtes, qui, dans les temps historiques, ne parlait plus d'autre langue que la langue des Gaulois ou Celtes.

Parmi les usages celtiques qu'avaient les Fir-Bolgs, la tradition leur attribue celui d'élever des tumulus, des monuments mégalithiques, quoique les plus con-

sidérables de ces monuments ne leur soient point attribués. En Angleterre, de même, on signale les restes brachycéphales trouvés dans les *round-barrows* qui paraissent se rapporter aux frères des Fir-Bolgs d'Irlande.

Au huitième siècle avant l'ère chrétienne, peu de temps après la venue des Fir-Bolgs, la tradition, suivant les Annales des Quatre Maîtres, fait arriver un peuple nouveau : il s'appelait la race de la Déesse Dana ou des Dieux de Dana : ce sont de grands hommes blonds aux yeux bleus, des druides autrement organisés que les druides bretons, avec une mythologie différente et qui paraît antérieure. Ce peuple à organisation sacerdotale conquiert l'Irlande sur les Fir-Bolgs et les assujétit. Un vieux poème bardique sur la bataille de Moytura où les Dananniens vainquirent les Fir-Bolgs, contient une particularité bien remarquable, que Lady Ferguson a signalée dans son excellent livre *On the Ancient Irish before the Conquest.* A l'époque où le poëme fut écrit, les Gaëls d'Irlande ne portaient depuis bien des siècles que des glaives de fer : cependant les bardes se souvenaient si bien de l'âge du bronze, que l'auteur du poëme explique la différence qui existait entre l'armement des Dananniens et celui des Fir-Bolgs ; ces derniers n'avaient que de mauvaises épées triangulaires, larges, courtes, mal fabriquées ; les autres avaient des épées plus longues, mieux fabriquées, mieux affilées, de forme élégante Or, vous pouvez vérifier au Museum de l'Irish Royal Academy l'exactitude du poète : ces deux sortes d'épées sont rangées dans les vitrines à côté les unes des autres. Vous avez là les armes dont se servaient les deux peuples rivaux il y a 2,500 ans.

J'ai fait remarquer l'accord qui me paraissait exister entre les observations anthropologiques et la tradition. Il y a aussi accord entre la tradition et les philologues, les linguistes. La linguistique nous montre une grande famille de langues, la famille aryenne, se formant dans l'Asie centrale, et en conclut que nos aïeux, ceux-là du moins qui nous ont donné nos langues européennes, sont venus de cette région. La tradition irlandaise ne remonte pas jusqu'à l'Asie centrale, mais elle est sur la route : elle fait venir les diverses colonies de la Thrace, de la Grèce, c'est-à-dire du Pont-Euxin et de l'Asie-Mineure, en résumé, de l'Orient. Peu importent les fables, et les infiltrations classiques, relativement modernes, qui altèrent ici les vieux souvenirs celtiques ; le fond, c'est la marche des immigrations d'Orient en Occident. Je ferai observer que la tradition welche ou cymryque de Galles est en accord avec la tradition irlandaise. Lhu Gadarn, ancienne divinité que les Triades transforment en conducteur de peuple, amène les Cymrys du pays de l'Été (*Bro haf*), où, dit la glose, est à présent Constantinople.

Pour les Dananniens, les Tuatha-De-Danann, il y a quelque chose de particulier, et qui mérite grande attention. Ils ne viennent pas tout droit de l'Orient ; ils viennent de Lochlin, c'est-à-dire de la Scandinavie.

Il y a des traditions qui les font venir 1,200, et jusqu'à 1,500 ans avant l'ère chrétienne ; mais la plus accréditée, celle qu'ont choisie les *Quatre Maîtres*, dans leurs grandes Annales d'Irlande, fixe leur avénement au huitième siècle seulement.

Or, les études des savants du Nord nous fournissent ici un rapprochement très frappant. Les savants Suédois et Danois font remonter approximativement à huit siècles environ avant l'ère chrétienne l'arrivée en Scandinavie d'un peuple qui succède à celui qui élevait des monuments mégalithiques. Ce nouveau peuple construit des tumulus où il n'y a plus de grottes de grandes pierres, mais des chambres funéraires en petits matériaux, où l'on trouve les guerriers non incinérés, avec leurs grandes épées de bronze, plus longues, plus larges, plus lourdes que les épées irlandaises, et parfois avec les restes de leurs vêtements. Ces conquérants sont, j'en suis convaincu, les Cimbres de l'histoire romaine, Celtes de race, et partis du Pont-Euxin pour le Nord à la même époque où leurs frères les Bretons en partaient pour l'Occident. L'archéologie ne signale dans la Scandinavie rien d'intermédiaire entre ces hommes aux grandes épées de bronze et aux ornements d'or, auxquels appartenaient aussi les grandes trompettes de bronze,—rien d'intermédiaire, dis-je, entre les Cimbres et les Scandinaves, les guerriers aux épées de fer et aux ornements d'argent, qui ne paraissent dans le Nord qu'au commencement de l'ère chrétienne.

Un passage du grand géographe Strabon me paraît se rapporter à la migration des Cimbres et des Bretons vers le Nord et l'Ouest. Strabon rappelle une tradition suivant laquelle une double émigration de Cimmériens et de Vénètes ou Hénètes

serait partie du Pont-Euxin à une époque postérieure à la rédaction de l'Iliade, mais antérieure à cette autre émigration cimmérienne donc parle Hérodote et que détermina l'invasion des Scythes six siècles avant notre ère. Cela nous donnerait encore à peu près huit siècles avant notre ère, l'Iliade étant considérée comme datant d'environ neuf siècles avant Jésus-Christ. Les Vénètes sont restés celtisés et mêlés aux Celtes en Italie, en Armorique, en Galles, en Écosse.

Voici comme ces migrations des Cimmériens ou Cimbres me paraissent nous ramener aux Tuatha-De-Danann. Les Cimbres remplacent dans le Nord le peuple des monuments mégalithiques. Or, la tradition irlandaise fait venir les Dananniens de Scandinavie à une époque qui se rapproche de la venue des Cimbres dans le Nord. N'est-il pas probable que la caste sacerdotale du Nord a émigré devant les conquérants, avec une partie de la population, et qu'elle est arrivée en Irlande, où la tradition lui attribue les plus imposants des monuments mégalithiques, Newgrange et autres?

A propos des Cimbres, Pline cite quelques mots de leur langue, qui ont une physionomie tout-à-fait bretonne, et Tacite nous dit que les Æstii (Estoniens?) parlent une langue très voisine du breton.

Pour me résumer sur les Dananniens, ils sont, à mes yeux, une branche des premières migrations celtiques dont Némedh est le prototype. Ils auraient été les constructeurs des monuments mégalithiques en Scandinavie, pendant que d'autres Celtes primitifs, leurs frères, construisaient nos monuments de Gaule (Bretagne et autres), d'Albion, etc. Newgrange et les autres grands monuments dananniens d'Irlande seraient donc postérieurs à Carnac, Locmariaker, etc., quoique appartenant à la même tradition et à une branche analogue des Celtes. Les signes symboliques des monuments de Bretagne et ceux des monuments irlandais, sans être absolument pareils, sont très analogues; il n'y a que ce qu'on pourrait nommer une différence de dialectes.

Les Tuatha-De-Danann, vainqueurs des Fir-Bolgs, furent, à leur tour, deux siècles après, suivant la tradition, vaincus par de nouveaux conquérants, les Scotts ou Milésiens, clans héroiques, qui subjuguèrent les tribus sacerdotales. Les Milésiens, eux, seraient venus du Sud-Ouest, comme les Dananniens, du Nord-Est. Ils étaient partis de l'Espagne. Ils étaient moins blonds, châtains; ils semblent avoir été de race plus ou moins mélangée: je les appellerais volontiers des Celtibères. Je poserai seulement deux questions en ce qui les concerne: 1°. Avaient-ils déjà les armes de fer quand ils arrivèrent? Les Gaulois du Danube, qui, après avoir envahi l'est de la Gaule, envahirent l'Italie, avaient déjà les épées de fer lorsqu'ils prirent Rome, près de quatre siècles avant notre ère, et les Celtibères, de leur côté, eurent de bonne heure des glaives de fer, et de meilleure trempe que ceux des Gaulois.

2°. Ce qu'on dit de la religion des Milésiens est singulier. Tribus héroiques, ils devaient avoir des dieux héroiques; on leur attribue cependant des dieux cosmogoniques; Crom, leur grand dieu, est un Chronos, un Saturne: son nom veut dire *courbe*, la courbe génératrice du cercle qui se referme sur lui-même: il est entouré de douze dieux inférieurs, comme une année mystique avec ses douze mois. Cela conviendrait bien mieux aux Dananniens qu'aux Milésiens. Serait-ce une partie de la mythologie danannienne dont Cormac ne nous parle pas dans son *Glossaire*, lorsqu'il cite la déesse Dana et la famille de dieux issue d'elle? Les Scotts auraient-ils reçu ce mythe des Dananniens?

Je terminerai, quant à ces vieux peuples, en émettant le vœu que l'on entreprenne de fouiller les tumulus irlandais qui passent pour les plus anciens, ceux qui sont censés être les tombeaux de Beath, d'Eire ou Ceasair, et autres personnages prétendus conducteurs des premières colonies. On n'y trouvera pas les restes de ces êtres mythiques; mais on pourra y trouver des objets archaiques très intéressants pour les études pré-historiques ou, pour mieux dire, pour les études des origines de l'histoire.

Permettez-moi d'ajouter une observation personnelle: j'ai visité une partie des comtés de Galway et de Mayo: je comptais y rencontrer en majorité les descendants des Fir-Bolgs: j'ai vu au contraire dominer dans cette contrée la race blonde aux yeux bleus, de beaucoup la plus nombreuse.

Dans la séance du vendredi 16, M. le major-général Lane Fox a lu un très intéressant rapport sur le camp de César, à Folkestone, et sur le Mount Caburn,

en Sussex. Les observations de son rapport peuvent s'appliquer à plusieurs des anciennes fortifications appelées en France *camps de César*, et qui sont d'anciens *oppida* celtiques occupés bien aprés César par les Romains; mais un plus grand nombre de ces *oppida* celtiques, en France, n'ont jamais été occupés par les Romains: je citerai le prétendu *camp de César* près Dieppe, auquel une tradition sans doute mieux fondée donne le nom de cité de Lime et où l'on trouve des objets de provenance celtique très ancienne.

J'émettais le vœu que l'on fouillât les tumulus irlandais réputés les plus anciens; la fouille pratiquée dans un des tumulus de Moytura a déjà donné un résultat: ce tumulus passe pour le tombeau d'un des chefs des Fir-Bolgs. On y a trouvé une urne très primitive, où les ornements fort simples paraissent avoir été creusés avec l'ongle dans la terre avant la cuisson. Ceci se rapporte très bien avec les traditions sur les Fir-Bolgs, qui passent pour beaucoup moins civilisés que leurs vainqueurs les Tuatha-De-Danann. A ceux-ci appartiendraient les urnes beaucoup plus finement ornées et de forme assez élégante, trouvées dans d'autres tumulus, et très analogues par le style avec celles des monuments de France.

Je remercie la savante assemblée d'avoir bien voulu m'entendre et serai très satisfait si quelques-unes des personnes éclairées qui la composent prennent intérêt aux questions que j'ai touchées et contribuent par leurs lumières à les résoudre.

Une dernière observation me revient à propos de l'écriture Ogham. Il ne paraît pas douteux qu'elle provienne des Tuatha-De-Danann. S'ils ont habité la Scandinavie avant l'Irlande, ils n'y employaient pas encore l'Ogham, puisqu'on ne le trouve pas sur les monuments mégalithiques du Nord; c'est donc depuis leur arrivée en Irlande qu'ils l'ont inventé, et l'on peut le qualifier spécialement de caractère druidique irlandais.

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2. *On some objects of Ethnological Interest collected in India and its Islands. By* V. Ball, *M.A., F.G.S.*

Mr. Ball exhibited and described a number of objects which he had collected in some of the least-known and wildest parts of India, and in the Nicobar and Andaman Islands.

From the peninsular there were a series of stone implements, having a marked resemblance to certain well-known forms of wide distribution. There were also some peculiar adze-shaped implements, found in Western Bengal, which had served to confirm a previously expressed supposition* as to a prehistoric connection having existed between the *Mundas* of Bengal and the *Muns* of Burmah.

Other objects shown were battle-axes and musical instruments used by the Khonds of Orissa; fire-sticks from Sambalpur; and boomerangs from Katiawar.

Nicobar Islands.—Photographs of the villages and people of these islands served to illustrate the peculiarity of the structure of the houses and the costume of the people, which latter was further exemplified by some wooden figures, which the author considered were rather to be regarded as effigies of the departed than as idols. The tail-like strips of cloth which hang from the waist and trail on the ground were probably the cause of the ancient belief in the existence of tailed men on some of the islands in the Bay of Bengal. In one of the editions of Ptolomy's map, islands which were not improbably intended to represent the Nicobars are labelled "*Satyrorum insule tres quarum incole caudas ut sunt satyrorum habere dicentur.*" Other objects from the same islands were a specimen of picture-writing; ear-cylinders; cocoa-nut-shell water-vessels; a copper-headed hog-spear, and a large sheet of cloth made of the beaten bark of a species of *Celtis.* The author gave his reasons for believing in the existence of a Negrito race similar to the Andamanese in the interior of the Nicobars.

Andaman Islands.—The objects from these islands which were exhibited and described were, human skulls adorned with shells, and which had been carried by the relatives of the deceased slung on their shoulders; glass bottle flakes, used for shaving; necklaces of turtle bones; a cooking vessel of sun-dried clay in a bamboo frame; bows and arrows of peculiar shapes; bones of turtle and Dugong from a

* By General Sir Arthur Phayre.

trophy; and oysters from a kitchen midden, the latter being remarkable from the fact that the Andamans of the present day do not, it is said, eat oysters, though they do eat other shell-fish. In conclusion the author remarked that ingenious in construction as some of the objects were, their invention probably dated back to a long distant time, since, in his experience, no savages of the present day ever invented a new implement or changed the manner of performing any single custom of their lives.

3. *Notes on the Tribes of Midian. By* CAPTAIN R. F. BURTON.

See Section E, p. 630.

4. *Notes on some Tribes of Tropical Aborigines. By* T. J. HUTCHINSON, *late Her Majesty's Consul at Callao.*

The memoir commenced by the author's statement of the tribes he was about to speak of being some of those in the tropical regions of West Africa and South America, with whom he had become acquainted during his twenty-three years of going to and fro in climes beyond the seas. Its chief object was to tell peculiarities of these tribes—to show the analogies in superstitions and social barbarities, as well as in a sort of indigenous civilization, amongst peoples of different races, dwelling on different sides of the globe. The Aborigines of Tropical Africa were first introduced under the different heads of—1. Pagan Superstitions. 2. Domestic Slavery. 3. Polygamy. 4. Cannibalism. 5. Social Barbarities. 6. Idioms or Languages. A description was given of the peculiar ideas in parts of Western Africa about the first Creation of Man. From this the author went on to the Tropical African system of polytheism—Serpent worship in Fernando Po was described as existing in the fact of the skin of a large kind of boa constrictor, called the "Roukaronkon" being annually suspended from a tree in the "Reossa" (or large forum space for palavers), and all the children born within the previous year being carried out by their mothers, and their little hands held up to touch the tail of the serpent. The people of the Egbo or 'tiger' tribe have an idea of an Almighty power, whom they entitle "Abasi Ibum." But as he is believed to be the Creator of all things incomprehensible, they worship a subordinate god-head whom they entitle Idem-Efik. Their superstition of making what they entitle "devil houses" in obsequies for the dead, wherein are put furniture, drink, eatables, and cloth, were shown to be precisely the same as exist amongst the Mongolian tribes in the Feejee Islands, as described by Dr. Leeman. This people (the Efiks) at Old Calabar, likewise administer "Afias," or Ordeals, pretendedly to detect crime, but in reality to keep the slave class in subjugation. They have also a biennial custom of purifying their towns from evil spirits. Domestic slavery was described in Western Tropical Africa, where all the women, from the wives of Kings and Chiefs downwards, were described as slaves. There is a custom on the Gold Coast to buy or appropriate out of the *ménage* of domestic slavery a boy or girl, and bestow on him or her the title of Crabbah or "Oerah." This signifies that they are to be looked on as the soul or spirit of master or mistress. They are treated well, never asked to work, wear chains of gold round their necks, with a medallion of gold, and when their owners die they are killed to accompany them into the next world. The two social institutions of Polygamy and Cannibalism were touched on briefly.—An analogy was pointed out between the practice which existed amongst the Moxos, a tribe of South Americans now extinct, and the people of Old Calabar, when the author was out there twenty-five years ago, of the barbarous practice of killing twins. The paper touched on the tribes of South American Indians—the Tobas, Guaicaruses, Abipons, and Mocovis—seen by the author in the tropical parts of the Gran Chaco, which he traversed in 1863. The Chimoo people of Peru were also spoken of. Differences of idioms between the tropical Africans living almost in contiguous districts were related, and the same shown to exist in Bolivia (within the tropics also), where in one province thirty-seven different tribes of Indians existed in former times, each tribe having a different idiom, and many of them having such a limited knowledge of arithmetic as to be able to count only to five, and some to three.

5. *On the Prehistoric Relations of the Babylonian, Egyptian, and Chinese Characters and Culture.* By Hyde Clarke, *V.P.A.S., V.P.S.S.*

Referring to the relationship of these three groups of characters, the writer gave illustrations of a community of meaning and form, and of a diversity of sound. This indicated that the original words attached to the characters belonged to some earlier language different from these, and in which the sounds having identical meanings corresponded. Taking the cuneiform characters for **Ka** and **Ba** they were in opposition (equivalent to ⵣK). Together they formed the word **Kaba**, a well-known recognisable prehistoric negative used for Not, Death, &c. In Chinese the roots 7 and 75 for No and Not indicate a combination of the same characters (ⵣK). In the ancient Shwo wen there are three arms on each side, so that the original form may be indicative of two hands in opposition. Further, while in later times **Kappa** is **K**, in square Hebrew Caph is nearer to C, and Caph means the Hollow of the Hand and is female, and in opposition to its neighbouring letter Yod, which signifies the Hand or emblem of the man or male. On the other side Akkad 42 of Lenormant, sounding **Ka** and **ga** is a square character (originally converted from round O), and signifying Mouth, Speak. The square Chinese character 30 signifies Mouth, Speak, and sounds **K'eu** and **ga(p)**. No. 156 Akkad square signifies Presence (= Face) and enclosure (= Field). The Chinese character for Face 109, and for Garden 102, correspond to Akkad. No. 204 Akkad signifies both House and Speak, conjunctions of meaning for the same sound to be found in the African or prehistoric languages. No. 71 Akkad stands for Fish, Ship, equivalents for which are found in Africa. No. 459 Akkad (‖ or =) stands for Son, Water, River, also combined as one word in Africa. No. 354 Akkad signifies Tongue and Serpent, again combined in Africa. In Chinese square characters, converted from round (☐ for O), are used for equivalents prehistorically, and psychologically and philologically connected, as Round, Circle, Eye, to See, Sun, Moon, Face, Head, Ear, Mouth, to Say, Sound, Mother. The favourite sound in Chinese for this group is **M**, (as in English Mouth, Moon, Mother). This series is continued in the alphabets, the Phœnician, Sabean, **Safa**, and some of the features may be recognised in modern Roman as O. Indeed, in the alphabets many emblems of the ancient Nature-worship, or emblems may be recognised as I, ℵ, C, U, O, V, Θ, S, T, Δ? M, Φ, K. With regard to the comparative philology of Akkad, Mr. Clarke continued to resist the Ugrian classification of M. Ujfalvy, and showed that the roots in Akkad and in Ugrian can be identified with those of the languages of prehistoric character of the Old and New World, but remarkably in Houssa, Mandingo, Pulo, Timbuktu, Aku, of Africa. Thus they approach in their affinities the Kolarian group of India as much as the Ugrian, and must precede the Dravidian or Tamil. This afforded independent evidence, in contradiction of the Semitic theory of M. Halevy, that the transliteration assigned to Akkad words by Lenormant is correct. At the same time we must allow for an earlier epoch of culture in characters and in mythology, antecedent to that of the Babylonians, Egyptians, and Chinese, and corresponding to that of the moundbuilders. With regard to the Egyptian mythology Mr. Clarke gave illustrations of the prehistoric origin of Pasht (the moon) Seb [Shepi], (Siva), and Kaba. He again maintained with regard to —— and ⩘ that —— in cuneiform, the vowel A, is male, and ⋀, the vowel U and O, is female.

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6. *On the Spread of the Sclavs.* By H. H. Howorth.

WEDNESDAY, AUGUST 21, 1878.

The following Papers were read:—

1. *On Flint Implements in Egypt and in Midian. By* CAPTAIN R. F. BURTON.

See Section E, p. 630.

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2. *Notices of an Expiring Race on the Bhutan Frontier. By* T. DURANT BEIGHTON.

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3. *Report of Excavation of a Bone Cave near Tenby, S. Wales.*

See Reports, p. 209.

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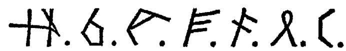
4. *Inscribed Bone Implements. By* J. PARK HARRISON, *M.A.*

At the meeting of the British Association at Plymouth last year, I exhibited some marks upon chalk, from the entrances of subterraneous galleries, at Cissbury, near Worthing, made by neolithic flint-workers for the purpose of obtaining materials for tools and weapons. They were of two kinds:—

1. Symbols, such as are often seen on ancient coins.



2. Simpler signs, and straight lines in different combinations.

Both descriptions of marks have been pronounced by eminent palæographists to be Runes, or adaptations of early characters by a semi-barbarous people.

No sufficient evidence, however, existed that the marks at Cissbury were contemporaneous with the galleries until March last, when the discovery of a skeleton buried with British rites, and with flint implements only associated with it, some ten feet higher than the entrance of a gallery, over which there were signs of a similar description to some in the second category (believed to be the earliest), removed all doubt respecting their antiquity.

Search has since been made for runes of early date in France, which has resulted in the acquisition of evidence of an inductive kind that brief inscriptions, possibly only charms, but perhaps names and dedications, were in use in very early times in Western Europe. Some twenty examples (all on implements of horn or bone) have been found in various museums, and the collections so opportunely brought together this summer at the Paris Exhibition.

There are also rune-like incisions on a bone which bears the remarkable outline of a horse, from the upper strata of the Victoria cave at Settle,* which are very similar to marks in the second category at Cissbury.† And it should be mentioned,

* 'Journ. Anthrop. Inst.' vol. viii. p. 182.

† I have also very recently heard that Runes have been found on a bone needle co. Kilkenny.

that the marks on the butts of two lance-points, of which graphic representations are given in the 'Reliquiæ Aquitanicæ,' are considered by the accomplished editor (Professor Rupert Jones) to be inscriptive.

It is not supposed that any of the early races, either in France or England, invented written characters. All that it is necessary to assume is that a knowledge of letters may have been acquired by commerce or "contact" from a people in a higher state of civilisation, just as bronze was introduced into neo-lithic France from the East at what appears to have been a less remote period.

In support of this I may mention that Professor Rhys, from a critical study of the Ogham characters, arrived some time back at the conclusion that they must have been founded on an earlier alphabet, which he considers would ultimately have been derived from the East.* Owing, however, to the perishable nature of the material (viz. wood) on which the earlier Runes are traditionally supposed to have been inscribed, no remains were believed to be in existence.

It is important, so far as the more distinctive forms at Cissbury are concerned, that the significant fact should be known that coins have been found on the coast of Sussex, which Mr. Ernest Willett informs us are of the type of those of Sex, a Carthaginian colony in the South of Spain: † and some of the Runes of that district are like the symbols at Cissbury last alluded to.

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5. *The Primitive Human Family. By* C. STANILAND WAKE, *M.A.I.*

After an examination of the theories of Mr. MacLennan, Sir John Lubbock, Mr. Morgan, and Mr. Herbert Spencer, all of which assumed that, owing to the uncertainty of paternity, the primitive human family was based on kinship through the female only, it was shown that such an assumption is not consistent with the social phenomena exhibited among uncultured peoples, which require the full recognition of relationship through the male as well as through the female, and that, while the clan or gentile organization is based on the latter, the primitive authority of the father as the head of the family is perpetuated in the tribal organization.

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* See 'Lectures on Welsh Philology.' Trubner, p. 366.

† 'Numismatic Chron.,' 1878, vol. xvii. New Series.

DEPARTMENT OF ANATOMY AND PHYSIOLOGY.

CHAIRMAN OF THE DEPARTMENT—R. McDONNELL, Esq., M.D., F.R.S.

THURSDAY, AUGUST 15, 1878.

The Department did not meet.

FRIDAY, AUGUST 16, 1878.

Dr. McDONNELL gave the following Address:—

SINCE this Association met twelve months ago, the science of physiology has suffered an irreparable loss. In February last, Claude Bernard died, in the sixty-fifth year of his age. He was interred with a degree of pomp never in this country, and rarely even in France, accorded to men of science. His country showed how highly and how justly they estimated the merit of a man who—gentle, unobtrusive, modest—by the greatness of his genius and the brilliancy of his many discoveries, shed a lustre on the land which gave him birth.

It was my privilege to have been at one time a pupil of this illustrious physiologist. It will be my pride if I can show to a thoughtful and cultivated audience, such as I have the honour to address, that the discoveries of my honoured master, although of necessity made by experiment on animals, have added much to that stock of knowledge which has conferred the greatest benefits upon mankind.

In an address like this, limited to a short time, it would not be possible to give a detailed account of the work accomplished by Bernard. To do so would be to give a history of the progress of physiology for the last five-and-thirty years. His researches were so extensive and some of his discoveries so vast, that, by comparison, they seemed to make others appear small, as the gigantic Californian pine seems to dwarf a goodly-sized oak which grows alongside it. Hence we speak of Bernard's less important researches—of his minor discoveries, although of sufficient magnitude to have seemed great if made by another. Of these I cannot speak at length. Yet some of my hearers well know that the services which Bernard has rendered to science by his researches on the pneumogastric nerves, the fifth pair, the chorda tympani, the facial, etc., are not small. Assuredly, the same may be said for his observations on "recurrent sensibility;" on the blood pressure and the gases of the blood; on the variations of colour in this fluid according to the active or passive condition of the functions of the organ traversed by it; on the variations of temperature during these conditions of functional activity or inactivity; on the elective elimination by the glands of substances introduced into the economy, or of those which, as morbid products, accumulate in the system as the result of certain morbid states; on the special character of the action of the varieties of the salivary secretions; upon the influence of the nervous centres on the secretion of saliva; on the electric phenomena manifested in nerve and muscle; on albuminuria connected with lesions of the nervous system; and (notably in its important practical bearings on uræmia) on the modifications of the secretions of the stomach and intestines after arrest of the elimination of urea through the natural channels.

Claude Bernard, in truth, left his mark deeply on every aspect of physiology on which he touched. His discoveries, however, as regards the functions of the pancreas, of the liver, and concerning the vasomotor system of nerves, are those on which his fame will ever chiefly rest.

It is not too much to say, that, prior to the communications made by Bernard to the Société de Biologie, little or nothing definite was known of the normal action of the pancreatic fluid. Even a popular audience can form a judgment as to the practical value of Bernard's researches in this direction. Before the publication of his memoir the fluid secreted by the pancreas was regarded as something destined to dilute the bile and render it less acrid—its true action as a liquid taking a special and active part in the digestion of particular kinds of food was, we may say, unknown. Bernard was the first physiologist who obtained pure, healthy pancreatic fluid from a living animal. It was he who showed its reaction. He demonstrated its extraordinary digestive power, not only over fats, but over other alimentary matters. He proved it to be the only one of the digestive liquids which at once forms a complete and permanent emulsion with fats. It is true Dr. Richard Bright had before (in 1832) observed fatty diarrhœa as existing in cases of organic disease of the pancreas, but, in fact, his observations were barren, and did not serve to direct attention to the action of the pancreatic fluid in digestion until after Bernard's discoveries threw additional light on the question. Bernard's researches on this subject have been so thorough and complete that he has left little to be learned. Yet there are many excellent physicians, who in their daily practice profit by his discoveries, who know little of the steps by which these discoveries were made. They prescribe pepsine and pancreatine in one form or another, but oftentimes they know as little of the discoverers of these agents as the cheesemonger does about the secretion or coagulation of the milk from which the cheese is made which he sells over his counter. It is hardly honest in such persons to form and express a dogmatic opinion upon what experimental physiology has done for practice without conscientiously endeavouring to inform themselves on this subject.

As regards the work accomplished by the liver in the animal economy, Bernard did nearly as much as he did for the pancreas. As every one knows, the liver is a large organ; it performs duties the importance of which to the health and happiness of mankind can hardly be overrated. Yet up to the year 1857 medical men were in absolute ignorance of one half of what the liver does. They knew that it secreted bile; it was reserved for Bernard to discover another and no less important function hitherto unknown. The majority of those engaged in practice even still, I believe, look upon the liver as if the principal duty of this gland were nothing else than the secretion of bile. It is certain, however, that it does other work, little, if at all, inferior in importance to the formation of biliary matters, and quite as necessary to the maintenance of health. Its power of making and storing up for a time within its cells, a material resembling starch, constitutes, without doubt, one of its most important functions. This no person will for a moment doubt who takes the trouble of ascertaining by experiment the immense increase or diminution in bulk which the liver may be made to undergo in the space of a few days by such changes of diet as increase or diminish the amount of this starch-like material in its tissue.

It was in March 1857, that Bernard announced the important discovery of a material formed by the liver closely resembling starch or rather dextrine of vegetable origin, and, like it, readily changing into sugar in the presence of ferments. Some of those present are aware that I have ventured to differ from my illustrious teacher as to the ultimate destination of this substance in the animal economy. I prefer, therefore, to designate it by another name than that which he gave to it. He called it sugar-forming substance (glycogenic substance or glycogene). This name involves the supposition that it is destined for the formation of sugar. It is not quite fair in science to give names which point directly to one's own theory. As some of those who, like Dr. Pavy and myself, have investigated this subject with a good deal of care, have still reason to doubt the sugar-forming theory as regards this substance, we naturally prefer a name which does not involve this supposition. We wish it to be called animal starch or dextrine (amyloid substance

or zoo-amyline). But, call it by what name we may, its discovery stands forth as a great fundamental fact. It would be difficult to imagine a discovery more extended in its applications. In the course of his investigations on this subject, Bernard showed the influence of diet, of digestion, of inanition upon this function of the liver. He showed the influence of the nerves and nervous centres in relation to it. He made the important discovery of the production of diabetes artificially. He was led to discover a similar function as regards the formation of amyloid substance on the placenta. He built up an entirely new theory of diabetes, fundamentally changing the view hitherto held on this subject, and, in short, made the whole field his own.

It is obvious to every one who allows himself calmly to reflect for a moment, that no physician can be a good practitioner who does not know something of the work done and the duties performed by the heart, or the stomach, or the lungs, etc., in a healthy state. Diseases are deviations from health; to understand the one it is necessary to know something of the other. It must appear quite puerile, therefore, to any thinking person, the assertion that the discovery of an important new function in a great organ like the liver did not modify the practice of medicine and throw new light on disease, not of the liver alone, but throughout the whole frame. You will pardon me, therefore, if I again express my doubts of the intelligence or the honesty of those practitioners who treat contemptuously experimental physiology and such work as has been achieved by men like Claude Bernard.

Faust, in his great soliloquy, addressing the Sublime Spirit of good, says:—"Thou didst not grant to me merely the cold gaze of open-mouthed astonishment. Thou permittedst me to see into the depths of Nature as into the bosom of a friend."

It has been the lot, no doubt, of a few among those whom I address, to have exhibited to some of their friends the circulation of the blood, as seen through the microscope, in the web of the frog's foot. They will have been struck, no doubt, as I have been, by the effect which this spectacle, when witnessed for the first time, has on different observers. Some look upon it much as they would upon a clever conjuring trick. It is to them no more than a transformation scene on the stage is to a child. "How fast it goes," they say. They are astonished that anything of the kind should go on in a frog. The cold unintelligent gaze of open-mouthed wonderment is, perhaps, even too strong an expression for any emotion which stirs them. Others there are who are struck dumb by the sight before them. One sees at once that they have caught a glimpse of a boundless prospect—that they feel it has been granted to them to see more deeply into the bosom of Nature than they have ever done before. One perceives, to use again Goethe's words, that the Sublime Spirit has not turned to them his countenance in vain.

There is an anecdote which I have dreamed of—as true, perhaps, as many such anecdotes are, yet full of beauty—that when Malpighi first showed to the Pope, whose friend and physician he was, this marvellous sight, his Holiness, having contemplated it for some moments in silence, raised his hands and eyes to heaven, repeating the "Te Deum," then, kneeling, thanked God for having permitted him to live to see so impressive a sight. "Is it indeed true," he asked, "that this wondrous movement goes on within me and you and all men?" Being told that doubtless it was so, "Mirantur aliqui," he said, using the words of St. Augustin, "altitudines montium, ingentes fluctus maris, altissimos. lapsus fluminum et gyros siderum:—relinquunt seipsos nec mirantur!" Apparently, Pope Innocent XI. viewed with less jealousy and suspicion than many ecclesiastics are wont to do, those divine writings traced on the face of Nature (too little studied by the theologian), the interpretation and decipherment of which is the province and the pleasure of the man of science.

I have been led to this reflection, as it appears to me to explain the difference between various individuals when contemplating some new disclosure in natural science; it illustrates the fashion in which the discovery to which I next allude is viewed by different classes of minds. A small filament of nerve, no thicker than a tiny silken thread, is divided in a rabbit's neck. Immediately a change is observed in the pupil of the eye on the same side. The ear on that side is felt to be obviously hotter than the other; the blood-vessels on that side of the head throb and contain

more blood. This same small filament of nerve is galvanized, and the reversal of the above phenomena is found to take place. To some this observation is not only a mere meaningless juggler's trick, but a cruel one. To others it is a key which opens a chamber full of treasures. It is like a newly-discovered isthmus or bridge uniting two vast continents—that of the circulatory system with that of the nervous system. In this controlling power of the nerves over the calibre of the blood vessels lies the explanation of many of the most interesting phenomena which go on within us. The burning flush of shame, the cheek blanched with fear, the sudden activity of glandular secretion, as when an emotion of the mind causes tears to flow, or salt placed on the tongue causes the secretion of saliva. The activity of the brain in our waking moments, its death-like inactivity during sleep, the regulation of our temperature, etc., are, within the limits of health, phenomena connected with this controlling power of the sympathetic nervous system. Within the domain of disease, its applications are without end or number; from the sympathetic and often painful swelling of the milk glands (hardly to be regarded as a morbid action) to the condition of the blood-vessels of the brain which causes the dreaded convulsive seizure of epilepsy, this dominion of the sympathetic nervous system over the blood-vessels has a meaning and a practical importance.

It would be unjust to others to say that Claude Bernard was the sole discoverer of this vasomotor nervous system, as it is called. It would be equally unjust to his memory not to admit that his researches had a large share in this discovery. Pourfour du Petit and Dupuy had no doubt, long since divided the cord of the great sympathetic nerve in the neck, and noticed some of its consequences. But the real discovery of the vasomotor nervous system was reserved for our time. The illustrious physiologist (Dr. Brown-Séquard) who now fills the chair in the Collége de France, rendered famous by such predecessors as Bernard, Magendie, and Laennec, has no small share in this discovery, and, as regards its application to the explanation of the phenomena of disease, and its treatment, has accomplished more than any of his predecessors. We owe to Bernard the discovery of the principal results due to division of the cervical portion of the sympathetic nerve; assuredly the discovery is one in which experimental physiology has reason to triumph, for it must be regarded as one of the most valuable disclosures of modern science. It cements together the vast number of isolated facts which, since the days of Prochaska and Robert Whytt, have been accumulating upon the hands of physiologists, but which, in the length and breadth of their importance, even Marshall Hall himself did not appreciate. But let us turn to the other half of this experiment; let me remind you that Dr. Brown-Séquard in America, Professor Claude Bernard in Paris, and Dr. Augustus Waller in England, almost simultaneously observed that galvanization of the divided sympathetic is followed by a reversal of all the phenomena which have been already noticed to follow its division—the vessels contract, heat diminishes, secretion is checked. These experiments are illustrative of the influence of the nervous system over the vascular. They have formed the basis of physiological theories very widely differing from each other, and perhaps less striking but not less valuable experiments bearing on the same subject. The muscular tunic of the vessels which ramify through the body places them under the control of the nervous system as completely as is the heart itself. As the muscular structure of the heart, so the muscular structure of the vessels is subject to emotional and reflex influences. It is not only the blood-vessels of the cheeks which blush. The greater development of the muscular tunic in the vessels of glands and of the brain, shows that in those situations the arrangements for controlling the blood supply are even more complete than elsewhere. It is true that it has long been known that intimate relations exist between organs more or less remote from each other. The term sympathy has long been in use, and equally applied to the healthy functional activity as to the pathological disturbances of organs distinct from each other. In the eyes of the practitioner, the morbid sympathies (or reflex disturbances), such as occur in teething children, or, later in life, from irritation of the gastro-intestinal or genito-urinary systems, etc., have naturally eclipsed in interest the normal physiological sympathies, such as that between the uterus and mammary gland, the mucous membrane of the tongue and the salivary glands, etc. But be it remembered that they are closely

kindred phenomena, similar in mechanism, and, in fact, often passing into each other so gradually that it is impossible to say where the normal terminates and the morbid begins. It is hardly possible to conceive any kind of research which bears more closely than these upon the various maladies that flesh is heir to.

Some hard-hearted individuals, however, in these countries, confounding their own selfish feelings with true humanity, who, I would venture to say, have rarely spent days or nights of their lives watching at the bedside of real suffering,

> "Who live
> In mere mock knowledge of their fellow's woe,
> Thinking their smiles may heal it,"

who fancy themselves too humane to seek a remedy for human agony in an experiment which it would be painful to themselves to conduct—such persons have heaped much obloquy on the name of Bernard. Let me pass by these in silence. There are others who, admitting the greatness of his achievements and his power of kindling an enthusiasm for research among his pupils, think that these same results might have been attained by a less amount of repetition of experiment. Them I would truly respect. Most earnestly would I urge those physiologists who, either as original inquirers or as teachers, may follow in the footsteps of Claude Bernard, while they admire him as a sincere, zealous, patient searcher after truth, to imitate him in that, and avoid what they believe to have been his errors.

Bernard's discoveries, in truth, tell but a small part of the tale of all that he accomplished during his lifetime. He was one of those truly great teachers who exercise a great and expanding influence over the minds of their pupils. He possessed a gentle, mild, and thoroughly infectious enthusiasm. A conscientious worker, a sincere lover of truth, a marvellously dexterous experimenter, he possessed the power of expressing himself with great precision and great simplicity. His pupils in every part of the civilized world will indeed account him as one

> "Of those immortal dead who live again
> In minds made better by their presence: live
> In pulses stirred to generosity,
> In deeds of daring rectitude, in scorn
> For miserable aims that end with self,
> In thoughts sublime that pierce the night like stars,
> And, with their mild persistence, urge man's search
> To vaster issues."

The following Papers were read:—

1. *Observations on some Points in the Osteology of an Infantile Gorilla Skeleton.* By Allen Thomson, *M.D., LL.D., F.R.S.*

Dr. Allen Thomson exhibited the skeleton of an infantile female Gorilla, which he had prepared from a specimen sent him some time ago, and which is now placed in the Hunterian Museum of Glasgow University.

The first dentition had been recently completed, and the age of the animal was estimated to be from eighteen months to two years. It had been shot through the head and had sustained a fracture of the thigh, but had lived long enough after the injuries to allow a healing process to be set up round the two apertures by which the lead pellet had passed through the opposite parietal bones of the cranium, and the fractured femur to be reunited by bone.

The author reserved for another opportunity the fuller account of the state of ossification of the bones of the skeleton, and limited his remarks for the present to several points in the osteology of the skull, vertebral column, ribs, and sternum.

In instituting a comparison between the skull of the infantile gorilla and that of the adult or of other animals, the author pointed out the importance of adopting a reliable standard position in which the skulls submitted to observation should be placed so as to secure uniform results; and, following Professor Flower, gave the preference to that recommended by Broca, in which the horizontal plane of the skull is made to coincide with that of the visual or orbital axes; and he showed,

by reference to drawings of the young and adult gorilla skulls, and those of other animals and of man, the necessity and advantages of such a standard in enabling the observer to make accurate corresponding representations and measurements of dimensions and directions. The resemblance of the view taken in the *norma facialis* of the infantile gorilla to the human skull was very striking.

In its general form this skull, as belonging to the infantile age, like that of its congeners and of man, differs remarkably from that of the adult; and in the case of the gorilla and orang, more particularly of the male, in the proportionally large size of the cranial part, the smaller size of the face, jaws and teeth, and in the entire absence of the crests of bone which attain such an enormous size in the adult male gorilla. In the infantile condition there is probably little or no difference in the form of the skull in the two sexes; but as age advances, and more especially as the second dentition appears, the distinctions arise by the greater development of the jaws and by the gradual approach and elevation of the temporal ridges, which remain distinct in the female, but rise into the sagittal and occipital crests of the male. In the skull shown there was as yet no appearance of the temporal lines, except in the commencement at the zygomatic process of the frontal bone. The double ridges on each side described by recent authors come to be obvious only at the change of the dentition.

For comparison with the human form the skull of a child of about two and a half years of age with the first dentition recently completed was employed, and many points of interest were brought out. Among these the capacity of the cranium may be mentioned. That of the child's skull now referred to was 64 cubic inches, that of the infantile gorilla $23\frac{1}{2}$, while the average adult human skull may be stated at 85 cubic inches, and that of the adult male gorilla at 33, and of the female at 28 cubic inches.

The author then referred more particularly to a point in the osteology of the skull which had excited considerable interest since the researches of Virchow and Gruber had thrown some light upon it, viz. the mode of union of the several bones which meet at the antero-lateral fontanelle of the fœtal skull, or the *ptereon* of Broca. It is now known that considerable differences in this respect occur in the human skulls of the same and different races of men, and it has long been known (Owen) that among the anthropoid apes there are differences of a similar kind, and that these differences are in some instances at least connected with the existence of a separate bone in the seat of the place of meeting at the ptereon, of the frontal, parietal, squamous, and alisphenoid bones, to which the name of epipteric has been given by Professor Flower.

In the great majority of human skulls, as well known to anatomists, the anterior inferior angle of the parietal bone joins here the alisphenoid in a greater or less extent,* and thus excludes the frontal and squamous bones from mutual union; while in a smaller number of instances the alisphenoid and parietal are separated by the junction of the squamous and frontal bones.

Now, in the gorilla, as shown in the skull exhibited, and in nine other skulls of the same animal examined by the author, the mode of union at the ptereon is invariably squamo-frontal. In the chimpanzee he found the same kind of union to prevail as in the gorilla in 23 out of 27 skulls examined; but in two examples the union was spheno-parietal on both sides, and in two others it was squamo-frontal on one side and spheno-parietal on the other.

In the orang, again, a greater difference was observed, for out of 30 skulls observed, the spheno-parietal union was present on both sides in 16, and the squamo-frontal in 7, while in 4 the mode of union was different on the two sides, and in 3 there existed the intervening epipteric bones, occupying as it were the common territory.

In 9 skulls of the Gibbon examined, 8 presented the spheno-parietal mode of union, and in the other case there was unilateral squamo-frontal union with an epipteric bone on the opposite side.

* The author referred here to the differences observed in the human skull, but as he is engaged in unfinished observations on this subject, he reserves their description for another opportunity

The author had made a considerable number of observations in different genera of Simiæ and Prosimiæ, from which it appeared that in the whole of the American monkeys examined without exception, amounting to 40 specimens from the genera Mycetes, Ateles, Cebus, Pithecia, Nyctipithecus, Callithrix, and Hapale, the union at the ptereon was spheno-parietal; and the same was found to be the case in the 18 skulls observed of Lemur, Galago, Loris, and Cheiromys.

In 96 skulls observed belonging to monkeys of the Old World, considerable variety was found. In 23 of Macacus, 1 Colobus, and 8 Cercocebus, all had squamo-frontal union; of 33 baboons, the same kind of union existed in 29, in 1 double and in 1 unilateral spheno-parietal union was observed, and in 3 cases epipteric bones were present. In 10 skulls of Semnopithecus observed, 9 had spheno-parietal and one squamo-frontal union; and in 20 skulls of Cercopithecus there was spheno-parietal union in 10 and squamo-frontal in 7 on both sides, and unilateral union of the two different kinds in 3.

The author left for future consideration the causes determining these varieties, more especially as connected with the origin and mode of ossification of the epipteric bone; but he showed the probability of a number of the varieties being attributable to the existence of such an intermediate bone at an early period, and to its union with one or other of the bones surrounding the ptereon. This union might be with alisphenoid, parietal, or squamous, but very rarely with the frontal bone. The author considers it doubtful that the epipteric is homologous with the posterior frontal, first described by Serres, afterwards by Rambaut and Renault, and more recently by Von Ihering (1872), but believed that the further explanation of the differences shown to exist in the mode of union of the bones at the ptereon is to be sought for with success in the history of their development, upon which he expected some light to be thrown by observations in which he was engaged.

Dr. Thomson also directed the attention of the section to some peculiarities in the mode of ossification of the bones of the trunk in the young gorilla, which he connected with the very frequent varieties observed in the adult condition of these and other anthropoid apes.

These observations referred—1st, to the condition of the sternum as regards the relative size of the presternum and mesosternum, and the number and place of implantation of the costal cartilages into the sternum; 2nd, to the number of vertebral ribs, and the occasional development of additional ribs upon the lumbar vertebræ; and 3rd, to the variations in the relative number and state of development of the lumbar, sacral, and coccygeal vertebræ in the four genera of anthropoid apes.

The author reserved to another occasion the fuller description of these observations, which were still incomplete.

2. *The Intrinsic Muscles of the Mammalian Foot.* *By* D. J. CUNNINGHAM, *M.D., F.R.S.E., Senior Demonstrator of Anatomy, University of Edinburgh.*

The typical arrangement of the intrinsic muscles of the pes is the same as in the manus, and this arrangement is seen to best advantage in the feet of certain of the marsupialia. In these animals the muscles are laid down in three layers, viz.:—

(1) A plantar layer of adductors.
(2) A dorsal layer of abductors.
(3) An intermediate layer of flexores breves.

According to this disposition each digit is furnished with three muscles—one from each layer.

Deviations from the typical arrangement may take place by suppression or fusion of certain of the elements of the different layers. Fusion of the constituents of the intermediate and dorsal layers is extremely common, whilst fusion of the intermediate and plantar muscles is a very rare occurrence.

But this disposition of the intrinsic foot muscles does not account for the presence of an opponens muscle. This muscle may proceed from one of two sources. Most commonly it is a development from the flexor brevis, and is thus associated

with the intermediate layer of muscles (e.g. man, lemurs, phalanging marsupials). It may be derived, however, from the plantar layer, and thus be associated with the adductors (e.g. lion, dog, leopard, puma, otter, and other digitigrade carnivora).

Lastly, in many adult animals, the relation of the intrinsic muscles to the metatarsus, both as regards their origin and position, corresponds with transitory conditions in the foot of the human embryo.*

3. *On the Gill Skeleton of Selache Maxima. By* A. MACALISTER, *M.D.*

The author directed the attention of the section to a fine specimen of the gill skeleton of this shark in the Museum of the University. The remarkable dentinal gill-rakers are preserved *in situ*, and the different portions of the cartilages of the palato-pterygoid, hyoid, and branchial arches are shown united. These are from a large shark cast ashore last year at Kinsale, but, unfortunately, much mutilated before it came into the hands of Mr. Cullen, the museum assistant of the University.

SATURDAY, AUGUST 17, 1878.

The Department did not meet.

* This paper will be found in an extended form in the 'Journal of Anatomy and Physiology' (Oct. 1878).

MONDAY, AUGUST 19, 1878.

The following Papers were read :—

1. *Phenomena of Binaural Audition.**
By Professor SILVANUS P. THOMPSON, *D.Sc.*, *B.A.*

This paper resumed an investigation on which the author had read a paper in Section A, the preceding year. The following points summarize the communication:

(a) There is an interference of the perception of sound: for the tones of two tuning-forks or other simple tones, differing slightly in pitch, and capable of interfering, are still heard to interfere when conducted separately to the two ears.

(b) When two simple tones in unison reach the ears in opposite phases, the sensation of sound is localised at the back of the head instead of in the ears. This and the preceding phenomenon are easily experimented upon with Graham Bell's telephones, or with indiarubber tubes to bring the sounds to the ears.

(c) This localisation of an objective acoustic "image" is independent of the pitch of the sounds.

(d) When the difference of phase is partial, the sensation is localised partly in the ears, partly at the back of the head.

(e) If the difference of phase be complete, and the intensities *unequal*, the acoustic "image," instead of being at the middle of the back of the head, is nearer to that ear in which the sound is louder.

(f) It is possible to discern the difference between two compound tones which differ only in phase but not in pitch, or in intensity of their component partial tones; for when two such compound tones are brought to the ears so that the vibrations of any partial tone present reach the ear in opposite phases, that particular partial tone is singled out and localised at the back of the head.

(g) When two simple tones are led singly to the two ears no differential tone is heard. There is some evidence that summational tones are heard.

(h) To binaural audition dissonances are excessively disagreeable, and ordinary consonances harsh.

(i) Vibrations mechanically conveyed to a point of the parietal or occipital regions of the skull at one side of the median line are apparently heard in the ear of the other side of the head.

2. *On the Theory of Muscular Contraction.* *By* G. F. FITZGERALD, *M.A.*

Assuming a muscle to consist of fibriles averaging $\frac{1}{8000}$th of a centimetre in diameter, and that they may be treated as a system of elongated cylinders of fluid with a superficial tension capable of variation by the action of nervous stimuli in accordance with M. Lippmann's experiments on the relations of electrical difference of potential to the superficial tension of fluids, it may be shown that a force of 4 kilogrammes per square centimetre might be produced, which approximates to the observed maximum contractile force. The striations in striated fibre are accounted for by the instability of uniform fluid cylinders, the necessity for a continual stimulus to keep up a given contraction by the constant repair going on in living muscle, and the heating of a muscle when it contracts, is completely explained by the fact that all fluid surfaces heat when they are allowed to contract under the action of their superficial tension.

3. *On the Nervous System of Medusæ.* *By* G. J. ROMANES, *F.L.S.*

TUESDAY, AUGUST 20, 1878.

The following Papers were read:—

1. *On the Excretion of Nitrogen.* Part II.—*By the Skin.* *By* J. BYRNE POWER.

I have already published a paper upon the renal excretion of nitrogen. Since then I have made some experiments on the cutaneous excretion of nitrogen, the results of which, and the *modus operandi*, I beg to lay before this Association for the first time. I may mention that I was induced to undertake these as well as my former researches with a view to the study of the physiological action of the hot-air bath, which I have found personally beneficial, in the hopes of establishing its utility on a scientific basis. In considering the action of prolonged sweating the question most practically important is, can the skin be made to act vicariously of the other organs of excretion, and, if so, to what extent? I believe that the generally received opinion is that the skin can be made so to act; and how far such opinion is warranted by experiment I hope in this paper to show more clearly than has hitherto been done. At present I confine myself to the cutaneous excretion of nitrogen, an element the excretion or retention of which in the system is a question of supreme importance, physiologically and pathologically. Without here attempting to quote the numerous authorities, I may shortly state what I consider to be the present position of this important question. Funke, by the results of his experiments upon himself and his two pupils published in 1853, not only verified those of Anselmino, Berzelius, Favre, and others as to the existence of nitrogen in the sweat, but proved its existence as urea, and was the only person, as I believe, who ever succeeded in making an estimation of the total quantity of nitrogen excreted by the skin in a given time until I attempted it myself. On the other hand, many experimenters—Voit, Ranke, Parkes, and others—have denied the existence of nitrogen in the sweat. They arrive at this conclusion inferentially, finding that the amount of nitrogen excreted by the kidneys and bowels was equal, and in some cases even exceeded, the quantity ingested, therefore leaving no room for any excretion by the skin. The most recent English authority on the point—the late eminent Professor Parkes, in the Croonian Lectures delivered by him before the College of Physicians in London, in 1871—after reviewing most of the authorities, thus concludes:—"On the whole, there appears to be little doubt that, apart from detached skin structures, the balance of evidence is against the passage of nitrogenous substances by the human skin." I do not think that the form of negative proof advanced by these authorities can stand before the positive results of those who obtain nitrogen in some form or other as a constituent of the fluid portion of the sweat. With regard to Funke, I consider that his estimation of the excretion of nitrogen per diem—amounting to as much as from 4·76 to 7·045 grammes—is excessive. He arrives at these results by multiplying the quantity obtained in an hour by 24, necessarily assuming the constancy of the sweat secretion, which assumption is contradictory to the statement made in another part of his paper, to the effect that "in one or two hours the quantity of the supply begins to diminish, even though the temperature and movements remain unaltered, and falls to such a minimum that one can scarcely perceive the increase even during greater intervals of time." Funke obtained the sweat from the arm only, and, having ascertained by measurement a ratio between its superficies and that of the whole body, he thus estimated the entire cutaneous excretion. His experiments were made under conditions of more or less violent exercise. I made mine on the body in a state of rest in the hot-air bath, considering results thus obtained more referable to conditions of disease. I shall now, without dwelling on my many failures, briefly state the mode of collecting the excretion which I finally adopted as being the

best. Having first tested the atmosphere of the ward in which I was about to operate to ascertain that it did not contain free ammonia in any quantity, I placed upon one of my hospital beds an indiarubber sheet, and over it another sheet of pure linen, upon which the person to be experimented upon lay. Over his body was placed a wooden cradle or canopy, covered outside with a thick felt, and lined inside with linen, which coverings were to be carefully adjusted round his neck. To raise the temperature with the canopy I used the lamp-furnace invented by the late Surgeon-Major Wyatt, the flame from which fitted accurately through a hole in the coverings guarded by a wooden ring. Considering the spirit-lamp of Wyatt's furnace objectionable for many reasons, I substituted a Bunsen gas-burner. To insure the regular renewal of the air within the canopy, and to prevent its saturation, as well as to collect any free ammonia which might be evolved, I introduced a tube leading from a Bunsen air-pump, which tube was connected with two glass towers filled with large beads and charged with half an ounce of dilute hydrochloric acid of known strength. Through another hole in the canopy I introduced a Daniel's hygrometer, by which I was enabled to observe the temperature and calculate the degree of saturation of the atmosphere within. As the gas, water, and re-agents employed contained some small portion of nitrogen, my first task was to ascertain the constant error arising from this source. To effect this I performed three blank experiments, omitting only the introduction of the person to be experimented upon. The result was that I obtained a small quantity of nitrogen nearly equal in each case and having a mean value of ·063 grammes, that being the total amount collected in one hour under the experimental conditions. The water I used was Vartry water, and when I used it unfiltered I employed the above number as a constant. As it would be necessary to use filtered water in order to eliminate epithelium, I made three similar blank experiments, using filtered Vartry water, and obtained another constant amounting to ·0408 gramme of nitrogen, which I used in all experiments on filtered water. The method employed for estimating the nitrogen was that to be described hereafter. I commenced a series of experiments upon myself, with the assistance of my clinical clerk, Mr. Clune. One of these I shall now describe. I first took a sponge bath for the purpose of removing loose epithelial scales, as well as minute fibres from the under-clothing, which I always found adhering to the skin, and having noted my pulse, respiration, bodily weight, and temperature, I entered under the canopy. The coverings being carefully adjusted round my neck, the gas-furnace was lighted, the air-pump and hygrometer adjusted, and the experiment continued for an hour or an hour and a half, the time being carefully noted. Before leaving the canopy the pulse, respiration, and bodily temperature were again noted, also the mean temperature and point of saturation of the atmosphere within the canopy. On leaving the canopy I got into a bath containing 20 litres of Vartry water acidulated with an ounce of the dilute hydrochloric acid of known strength. I took with me into this bath the linen sheet upon which I had lain whilst under the canopy, and with it I gently rubbed myself so as to remove any loose epithelial scales. On leaving the bath I again weighed myself, and in twenty minutes after I again noted my pulse, respiration, and bodily temperature. I caused the linen and india-rubber sheets, as well as the towels containing the dilute hydrochloric acid, to be washed in the water of the bath, and then brought a specimen of it to my laboratory for analysis. The process of analysis of this water which I employed was briefly as follows:—I carefully measured 100 c.c., and poured it into a partial-distillation flask, which I altered to suit my purposes by shortening and bending the side tube upwards towards the mouth. I now took a porcelain dish, in which I placed a small quantity of pure sand carefully cleansed with hydrochloric acid, and subsequent washing with distilled water, and moistened it with a drop of strong sulphuric acid. Having placed the dish upon a water-bath, I inverted the flask into it, and, properly suspending it, carefully evaporated the water as it gradually flowed into the dish; I then removed the sand from the dish, and, mixing it with soda-lime, placed it in a small combustion tube, and proceeded to estimate the quantity of nitrogen contained in the 100 c.c. in the manner referred to in my former paper. Hence I calculated the quantity contained in the 20 litres, and from this quantity I deducted my constant, thus ascertaining the total quantity of nitrogen excreted by the skin during the experiment. I have described an experiment in detail, as all the others

were conducted in a similar manner, except when I filtered in order to get rid of epithelium, a circumstance noted in my tabular statement of results, in which case, of course I employed the constant for filtered water. I may here note that I examined the deposit from the water of the bath under the microscope, and found it to contain scarcely a trace of anything but epithelial scales. On comparing my experiments with those of Funke, we find that the quantities of nitrogen obtained by Funke are much greater than mine. This difference may arise from the circumstance noted already, that Funke's experiments were conducted under the conditions of more or less violent exercise, which I, accepting the views of Liebig, so strongly supported by the recent experiments of Professor Flint on the pedestrian Mr. Weston, believe to be always accompanied by waste of muscular tissue, and consequent increased execretion of nitrogen. I am aware that this view has been controverted by the experiments of several eminent physiologists, but I believe that my work tends somewhat to confirm it, though indirectly. I believe that the cutaneous excretion of nitrogen in normal healthy conditions is but small. But in my table will be found the results obtained from a patient suffering from Bright's disease (marked [c]), showing an excretion of nitrogen more than double the average amount in my own case (marked [a]). I note that in case [b] the renal excretion of nitrogen was considerable, increased by the use of the hot-air bath, a result I conceive of great importance, due, I believe, to the temporary febrile condition induced by the bath, evidenced by the increased rate of pulse and bodily temperature. I have since found this view confirmed by the experiments of G. Von Schleich, of Tubingen, showing an increased excretion of urea caused by the use of the ordinary hot-water bath. But I have not as yet had an opportunity of making further researches, on this point. I have again to thank my friend Professor J. Emerson Reynolds, under whose guidance my experiments were conducted, for his valuable and kind assistance.

Number of Experiment	Weight of Body		Temperature of Bath	Duration of Bath	Renal Excretion of Nitrogen per diem	Cutaneous Excretion of Nitrogen			
	Before Bath	After Bath				Total Nitrogen excreted	Nitrogen as insoluble matter—Epithelium	Nitrogen as soluble matter	
	lbs.	lbs.	Fahr.	h. m.	grms.	grms.			
1	124	123	107	1 0	11·56	0·049	0·01	0·039	
2	124	122·5	106	1 0	12·02	0·113			
3	124	123	111	1 30	10·86	0·129			
4	124	123	116	1 0	12·7	0·097			
5	124	123	116	1 0	10·56	0·113			Case A, healthy.
* 6	122·5	122	125	1 0	13·53	0·129	0·038	0·091	
* 7	122·5	122	124	0 45	—	0·081			
† 8	124·5	124	120	1 0	12·1	0·097	0·042	0·055	
† 9	125	123	118·5	1 0	—	0·129	0·058	0·071	
1	161·5	160·5	131	1 10	17·2	0·129	0·09	0·039	
2	161·5	160·5	142	1 10	22·3	0·161			Case B, healthy.‡
3	162·5	162	125	1 0	19·6	0·177			
1	155	154	124·7	1 0	—	0·337	0·0978	0·2392	
2	157	155	127·4	1 0	—	0·337	0·1578	0·1792	Case C. Bright's Disease
3	154·5	154	118·4	1 0	—	0·117	0·065	0·052	
4	156	154	123·8	1 0	—	0·257	0·137	0·1192	

* Experiments 6 and 7 made on the same day.

† Experiments 8 and 9 made on the same day.

‡ The mean renal excretion of nitrogen for three days immediately preceding was only 14·4 grammes.

2. *On a Direct Method for determining the Calorific Power of Alimentary Substances. By* J. A. WANKLYN *and* W. J. COOPER.

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3. *On the Aberrant Form of the Sacrum connected with Naegele's Obliquely Contracted Pelvis. By* ALLEN THOMSON, *M.D., LL.D., F.R.S.*

Dr. Allen Thomson exhibited a well-marked specimen of Naegele's obliquely contracted pelvis in a male adult, together with a series of eight sacrums presenting different forms and degrees of the abnormal development which is the most frequent primary cause of the pelvic deformity first described by Naegele.

Naegele's first description of this deformity was published in 1834 ('Heidelberg. Klinisch. Annalen,' vol. x. No. 4, translated in the 'London Medical and Surgical Journal,' vol. vii. No. 168), but he had already observed a case of it as early as 1803, and others in 1813 and 1825. In 1850 Naegele published at Maintz a separate and more extended memoir on the obliquely contracted pelvis, and some other pelvic deformities, illustrated with full-sized representations, in which he showed that the oblique deformity in question is not confined to one sex, but occurs in the male as well as in the female; though, of course, its presence in the female is more liable to arrest attention from its relation to difficulties in parturition.

Although Naegele had not fully described the nature of the abnormal condition of the sacrum which accompanies the pelvic deformity, yet he had figured that condition clearly as it occurred in different instances on the right and on the left side, and it may be inferred from his description and drawings that in the majority of the cases the deformity was of the nature of a congenital malformation. Dr. Edmund B. Sinclair, of Dublin, had the merit of detecting the existence of a similar deformity during life in a case which he has described in the 'Dublin Journal of Medical Science.' In this case Dr. Sinclair was inclined to attribute the origin of the obliquity to morbid degeneration in the vicinity of the sacro-iliac articulation, and he may have had sufficient reasons for doing so. But the specimens exhibited to the section by Dr. Thomson fully bear out the view recognised by Rokitansky, that the deformity of oblique pelvis is very frequently if not always of the nature of an aberrant kind or defect of development occurring in the first sacral vertebra; and Dr. Thomson's object was to show more clearly than had previously been done the nature of this aberration.

The most common form of the malformation may be described as one in which the first sacral vertebra presents on one side all the usual characters which belong to it as a constituent part of the sacrum—possessing, therefore, the large lateral mass which enters into the formation of the upper pelvis, and articulates with the ilium in the auricular surface; while upon the opposite side there is no sacro-iliac junction, an entire absence of the lateral mass, and the first sacral vertebra presents in its transverse and articular processes, its intervertebral foramen, the form of its body and arch, and in all other respects, the characters of a lower lumbar vertebra. There is, therefore, half a sacral vertebra on one side and half a lumbar vertebra on the other; the detachment of the vertebral arch (laminæ and processes), however, generally extending over to the sacral side.

The obliquity of form in the pelvis, and its consequences in other parts of the vertebral column, are most directly the result of the unequal support given by the sacro-iliac articulations of opposite sides. The author regards the ligamentous synostosis frequently found in these cases at the sacro-iliac articulation on the abnormal side, not, as has been supposed by some, as a cause of the deformity, but rather as a consequence of the greater strain thrown upon this joint by the curvature following upon the shrunken condition of the first sacral vertebra, and the absence of its connection with the ilium in the nonsymmetrical pelvis.

Of the eight specimens of sacrums exhibited, three presented the lumbar form in the upper piece on the right side, and four on the left side, while one was nearly symmetrical in form, but presented a partial retrogression, as it were, from the sacral to the lumbar form on both sides very nearly in an equal degree.

The specimens illustrated in an interesting way the different degrees in which the transition between the sacral and lumbar vertebral form might occur; and, in connection with the examples of symmetrical form, led the author to remark upon the variations in the number of sacral and lumbar vertebræ which occur not unfrequently both in man and animals, and, according to some observations which he has made, very commonly among the anthropoid apes.

With reference to this subject, the author held that the most common cause of the occurrence of six component pieces in the human sacrum (more frequent in the male than in the female) is the increased development and union of the first piece of the coccyx with the fifth sacral vertebra, without there being any actual increase in the whole number of vertebræ in these two portions of the vertebral column. But he further held it to be probable that in some instances, though very rare, an addition may take place to the number of sacral vertebræ by the conversion of the lowest lumbar vertebra into the sacral form; thus giving rise, in an instance in which there is the usual number of ribs and dorsal vertebræ, to the existence of only four lumbar vertebræ.

It is more certain that in instances of six lumbar vertebræ (with twelve developed ribs and dorsal vertebræ), the sixth lumbar vertebra may be regarded as a transformed sacral vertebra; as in an example of this kind observed by the author, the sixth lumbar vertebra showed a slight approach to the sacral characters, while the normal number of five sacral and four coccygeal vertebral pieces was still present, thus indicating distinctly the interpellation of an additional vertebra, and the transference, as it were, of one from the coccygeal to the sacral series, and of one from the sacral to the lumbar series.

Dr. Thomson showed also an example of a sacrum of four pieces, and pointed out that this might arise either from the conversion of the upper piece into the lumbar form or from the detachment and retrogression of the lower vertebra into the coccygeal form.

At the suggestion of Professor Macalister, Dr. Thomson exhibited from the Museum of Trinity College a skeleton of the wombat (*Phascolomys*) presenting the same unilateral retrogression of the upper sacral vertebra into the lumbar form which is the cause of the oblique pelvis in man, thus showing that the abnormal form of development which had been described is not confined to the human species.

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4. *Note on the Occurrence of a Sacral Dimple and its possible Significance. By* Lawson Tait, *F.R.C.S.*

The author had noticed casually amongst his hospital patients a curious pit-like depression or dimple in the skin over the lowest bone of the sacrum, and his attention had been drawn to a case in which it was present in a marked degree in all the children of a woman who had it. In one of these the pit was a centimetre in depth, its apex adherent to the aponeurotic structures, and it expanded outwards so that its mouth had a diameter of about 13 millimetres. Of the patients subjected to examination (for other and special reasons) he found no trace of it in 55 per cent.; in 22 per cent. it was faintly marked; and in 23 per cent. it was well marked. A double pit was noticed in about 6 per cent. of the cases. The average age of its occurrence was slightly over thirty-two years, and the average age of those in whom it was entirely absent was nearly forty-five years. In children averaging about five years it was found entirely absent in only 26 per cent., and it was well marked in 40·7 per cent. of the cases; so that there is a manifest tendency for it to disappear with age.

The author further described the appearances of a kitten which he had dissected, and in which there had been a *spina bifida* in the lower sacral vertebræ; all the vertebral elements below the seat of the malformation had been arrested in development exactly as is found in the coccyges of those animals in which a tail has been lost—man, the Manx cat, the guinea-pig, &c. The nervous nutrition of the posterior limbs had not been interfered with in any way.

The author suggested that the origin of such a curious variety as the Manx cat might have occurred in a sport of this kind, as such cases of *spina bifida* are known to live to maturity; and if it occurred in a male cat in a limited area like the Isle of Man, the perpetuation of the alteration of structures would be favoured.

He also suggested as a possibility that the pitting over the human sacrum, to which he had drawn attention, might represent some such process by which the tail which man undoubtedly had lost at some time or other in the history of his development, had been suppressed.

WEDNESDAY, AUGUST 21, 1878.

The following Papers were read:—

1. *The Rate of Cardiac Hypertrophy. By* WILLIAM H. STONE, *M.A., F.R.C.P.*

It may be accepted as an axiom that every reduction of physiological or pathological processes to known physical laws, even if only partially and approximately successful, is a step forward in science, and that if the whole disturbance of Nature's equilibrium, from the excessive complexity of the functions involved, be beyond our power of analysis, there is still some advantage and a gain to precise observation in cutting off and putting on one side such portions as are susceptible of accurate treatment. The predominance of vague, though necessary generalizations, such as that of vital action, is thereby materially diminished, and the direction is more closely indicated in which future efforts at advance may most judiciously be directed.

Of all parts of the human organism, there is none, after the simple muscular and bony framework, which belongs more distinctly to Physics than the apparatus of circulation, and its central motor, the heart. This organ is obviously nothing more than a double force-pump, furnished with two reservoirs and two pipes of outflow. It is true that the valvular apparatus, which is also duplicated, is furnished with complex muscular and tendinous appendages to regulate the tension and secure the apposition of the occluding surfaces. But in the main the problem of its action is hydrodynamical, and many valuable facts may be obtained by regarding it in a mechanical point of view. The height to which this force-pump is called upon to raise a given volume of fluid is obviously measured by the height of the animal to which it belongs, and even as early as 1769 Dr. Hales made experiments on horses, which showed the height of the column of fluid sustained by the heart's contraction, as transmitted through the large arteries, to be in horses about 9·14 feet.

Dr. Haughton, in his excellent and suggestive work on 'The Principles of Animal Mechanics,' has most ingeniously utilized an accidental opportunity afforded by an operation for computing the force when a large artery is divided in the human subject, at a vertical column of 2·58 feet; that ascertained to exist in the horse being 2·53 feet. It would, indeed, seem that the maximum hydrostatical force is about the same in the two animals, and probably not far different in the sheep and dog.

Besides (1) the statical pressure of the column equal to the animal's height, which has to be sustained, and (2) the force consumed in overcoming the inertia of the blood-mass, an important element in the work to be done is (3) the resistance offered by the capillary vessels to the flow of blood There is reason to believe, says Dr. Haughton, that in animals similar in bulk the arrangement and structure of the capillaries are such that the ratio of the squares of their cross-sections to their total length is practically constant. Supposing the co-efficient of capillary resistance to be the same in the man as in the horse, we can calculate, on Dr. Haughton's method, the hæmastatical pressure of blood in the human arteries. The left ventricle has a capacity of about 3 ozs., or 5 2 cubic inches, and beats about 75 times per minute.

Taking the usual equation of capillarity—

$$Q = A \times \frac{h.d}{l}.$$

Where Q = quantity discharged in a given time.
A = a constant.
h = the charge, or hydrostatical pressure.
d = diameter. l = length of tube.

Solving this for h,

$$h = \frac{Q}{A \times \frac{d^4}{l}}.$$

Substituting for Q the product of capacity and rate of pulse, and for the capillary resistance, its value found for the horse, we obtain—

$$h = \frac{5{\cdot}2 \times 75}{39{\cdot}3} = 9{\cdot}923 \text{ feet.}$$

There is a fourth element to be considered in estimating the heart's work, namely, the friction of the machine itself. This, in a state of health, is kept at its minimum by the beautiful contrivance of the smooth lubricated serous membrane of the pericardium. It will be seen that in disease this condition may be completely altered.

It appears from Dr. Haughton's calculations, resulting from comparison of several observations, that the average weight of the heart may be taken as $= 9{\cdot}39$ ozs.

Dr. Peacock's laborious collection of weights, both in health and disease,* gives a value not far distant from this: namely, "in persons from twenty to fifty-five years of age it is, in males, 9 ozs. 8 drachms, and in females 8 ozs. 13 drachms." But in disease this is entirely changed. The heart possesses a power of increasing its muscular force in proportion to any extra work that may be thrown upon it. In extreme cases the hypertrophy thus caused may be very considerable. Even without valvular disease of the organ a remarkable increase may occur, especially in persons whose occupation subjects them to sudden muscular strain, accompanied by forcible holding of the breath, as in the case of paviours working with their rammers. Dr. Peacock records a case in which the heart weighed 40 ozs. 12 drachms, though nothing, except some atheromatous change, was detected sufficient to explain the hypertrophy. In this instance, however, no note was apparently obtained by which the time during which the compensatory process had been going on could be ascertained.

The object of the present paper is to record briefly some cases in which one only of the above-named causes of increased strain was at work; and thus, by coupling together increase of weight with a fairly accurate statement of the time which had been occupied, to obtain an estimate of the rate at which the hypertrophic process proceeds in each instance.

These cases are four in number—

1. Two of valvular disease of the aortic valve, arising from injury, without any concomitant blood-disease (No. 2).

2. One of adherent pericardium, dating from a known commencement, unaccompanied by valvular or blood-disease, and showing the hypertrophy due to simple increase of friction in the propelling machine (No. 4).

3. One of congenital or very old atrophy of one kidney, increasing (3) the resistance offered by the capillary circulation, without valvular or pericardial disorder.

Case 1.—A robust man, aged 30, was kicked by a horse on the front of the chest. The animal lashed out with both hind legs at once, and landed a hoof fairly on either side of the sternum. This occurred on October 2nd, 1875. The man immediately began to suffer from short breath and other signs of valvular disease of the heart. In spite of this he managed to keep at his occupation of groom until February 2nd, 1876. On the 27th of the same month he died. On the following day the heart was found to measure transversely $8\frac{1}{2}$ inches, and in circumference 14 inches while *in situ*. It weighed 29 ounces. The aorta was laid open in front and the condition of its valves examined. On allowing a stream of water to run into the vessel, there was free flow into the ventricle. On looking into the valves from above, a triangular aperture was seen between the flaps, which appeared to be formed in the following manner. The posterior and the right anterior segment acted well, and were in contact along a great part of their adjacent borders. The left anterior segment, however, scarcely acted at all, its free border being widely separated from the

* 'On the Weight and Dimensions of the Heart in Health and Disease.'

edges of the other segments, and turning downwards towards the cavity of the ventricle. Its edge was puckered and folded, as if an effort had been made to fold it downwards. The whole of the segments were somewhat rigid and thickened, free, however, from atheroma and vegetations.

The mitral valve was healthy, and acted well.

The aorta was not materially diseased.

All the other organs were healthy.

From the injury to the day of death, 147 days, or exactly 21 weeks, had elapsed.

Case 2.—A dock-labourer, æt. 36, also in St. Thomas's Hospital, had been suddenly attacked when pulling at a sugar hogshead. His hands slipped, struck him a severe blow on the left side of the chest, and he fell backwards. He immediately felt severe pain in the region of the heart, and in the evening his breathing became difficult. He died 3½ months from the injury.

The heart was found to be greatly enlarged, weighing 23 ounces. The left angle of the posterior semilunar segment at the aortic orifice was found to be torn from its attachment, so that it was quite loose, and readily admitted of retroversion, allowing free regurgitation from the artery into the ventricle.

Case 3.—A French waiter, æt. 20, came into St. Thomas's for acute rheumatism. On January 12, 1878, he had a sudden attack of pericarditis, from which he had been perfectly free before. This proceeded to total adhesion, and after leaving the hospital for a time he returned and died on July 7, exactly 176 days, or twenty-weeks and a day, from the commencement of the disease.

All the valves of the heart and all other organs in the body were substantially healthy. The pericardium was, however, firmly and universally adherent. The heart itself weighed 19½ ounces.

Case 4.—A boy, 14 years of age, was admitted into St. Thomas's on August 22, 1876, suffering from obvious hypertrophy of the heart, but without evidence of valvular disease. I considered the case to be, like the last, one of adherent pericardium. It was difficult to obtain any distinct history from so young a person but, from information tendered by his relations, the following facts were established:

He had been quite well until three months before admission. He then "caught a severe cold," accompanied by cough, pain in the chest, short breath, and prostration. When first seen he was pale, œdematous in the face, suffering much from spasmodic cough. The heart was obviously enlarged, as was also the liver. The temperature was 98°·4. The urine of sp. gr. 1016, containing much albumen. This, however, disappeared after a fortnight's rest, and never returned to any appreciable extent.

A sphygmographic tracing of the pulse at the wrist, taken two months after his admission, showed the remarkable fact that the heart's pulsation was entirely under the command of respiration, so that when he held his breath, the tracing was reduced to a faintly undulated line. On the other hand, when he coughed, a wave of great force and extent was sent through the artery, somewhat resembling the healthy pulse tracing. He had occasional slight hæmoptysis and increased dyspnœa, under which symptoms he sank on November 20, 1876. The pericardium was found entirely free from adhesions, the heart weighing 19½ ounces, greatly hypertrophied, but without any valvular lesion.

The aorta and great vessels of the neck were extremely atheromatous, much thickened in places, but quite pervious.

The left kidney was atrophied, flattened, and of triangular shape, somewhat resembling the suprarenal capsule. Its vessels and the ureter were normal and pervious, but the vessels were only about half the size of those on the right side.

The arteries at the base of the brain were extremely atheromatous; the atheroma extending throughout their branches as far as the small vessels spreading over the convexity of the hemispheres.

On comparing the above cases, we obviously have three different causes, all of a physical character, but producing one and the same result—namely, hypertrophy. In the first two the permanent obstacle between the heart and the arterial system was broken down, and the momentum of the blood column was thus permitted to fall back upon the muscular structure itself, instead of being warded off by the re-

tentive tissue of the aortic valves.* The quantity propelled at each stroke can only have been the difference between what was admitted through the mitral orifice and what regurgitated through the partially patent aortic orifice. Besides this, there must have been the constant backward pressure of arterial elasticity bearing on the cardiac walls, even during the period of rest in the circulatory cycle. In the third case an impediment was caused to the action of the heart itself by additional friction due to the destruction of its serous covering, and the additional mass of false membrane as well as adjacent tissues, which it was thus compelled to keep in movement at every contraction. In the fourth and last case, the only assignable cause for the great enlargement must be the increase of what Dr. Haughton has named the capillary coefficient. It here stands for the resistance, not of the capillary system alone, but of the whole arterial network, from the aorta onwards, which is described as highly rough and atheromatous. In the transparent structures on the surface of the brain this condition could be seen to penetrate even into the smallest vessels, and it may, therefore, be fairly assumed to have been universal. It has been shown by Dr. Bright that disease of the kidneys, unconnected with valvular disease or disease of the aorta, has a tendency to produce enlargement of the heart. Dr. Peacock proves this statistically by giving the proportion of enlarged hearts as eleven out of eighteen cases examined. The smaller arterioles in cases of renal disease have also been demonstrated by Dr. Johnson to possess a largely increased amount of muscular fibre. Whether the hypertrophy in this case was originally due to this cause, or went backwards to the insufficient renal excretory surface supplied by the single healthy kidney, it is difficult to say. Placing the cases in a tabular form:—

	Duration of illness	Normal weight	Actual weight	Remarks
Case I.	147 days or 21 weeks	9 ozs.	29 ozs.	20 ozs. gained in 21 weeks
„ II.	14 weeks	9 „	23 „	14 ozs. „ in 14 weeks
„ III.	25 weeks	9 „	$19\frac{1}{2}$ „	$10\frac{1}{2}$ ozs. „ in 25 weeks
„ IV.	26 weeks	7 „	$19\frac{1}{2}$ „	$12\frac{1}{2}$ ozs. „ in 26 weeks

The rate of the first two cases due to aortic lesion is very similar, being nearly an ounce per week; the third, due to pericardial friction, is about half this amount; in the last, though the actual weight gained is not far different from that of the third, the ratio to the normal size of the organ in a boy of 14 is considerably greater, and the hypertrophy in proportion to the muscular development of the patient much more marked. It may be noted that the pregnant uterus increases by about twenty-four ounces in nine months or thirty-six weeks, or two-thirds of an ounce per week, a quantity far less than that shown by the heart.

* Dr. Haughton writes on this subject:—"The chief resistance in the open condition of the valve arose from the *vis inertiæ* of the blood column, which had to be set in motion afresh at every heart-stroke.'

Section E.—GEOGRAPHY.

President of the Section—Professor Sir C. Wyville Thomson, LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S., F.L.S.

THURSDAY, AUGUST 15, 1878.

Professor Sir C. Wyville Thomson gave the following Address:—

In doing me the honour to select me to preside over this Section on the present occasion, the Council of the British Association have doubtless had in view the part which it has been my privilege to take in contributing to the physical description of the earth, as director of the civilian scientific staff on board Her Majesty's ship *Challenger*. I will not, therefore, apologise for following the example of several of my more immediate predecessors in leaving to others the subject of topographical geography, of which I have never made a special study, and directing your attention for the short time at my disposal to advances which have been made of late years in certain directions in the application of the physical and natural sciences to the illustration of the general condition of the earth.

Before doing so, however, I must refer to the great geographical event of the year which has passed since the geographical section of the British Association last met—the return of the African explorer, Henry Moreland Stanley. As the graphic account which Mr. Stanley has given of his journey "through the dark continent" is in all our hands, and as we may hope to have an opportunity during this meeting of hearing something further of his adventures from the great traveller himself, it will not be necessary for me at present to enter into any details either with regard to the course taken by his expedition or to the brilliant results which it has achieved. It is, however, incumbent upon us in this place to acknowledge once more the flood of light which Stanley has thrown upon the geography of Central Africa, and to express our wondering admiration of the iron will and the daring intrepidity which carried him through these long years of labour and difficulty and danger. Although, in reading Stanley's narrative, we may be forced to regret some of the dark scenes by which his terrible march was chequered, still no one who has not himself had some dealings with savages can fully understand how entirely the action of a leader, solely responsible for the lives of his party, must be guided in every emergency by considerations which he alone is in a position to weigh.

During the last few years, a factor, so altered in its proportions that it has appeared almost new, has entered into the calculations of the naval executive departments of all the maritime powers; and in harmony with the rapid advance of natural knowledge and the widening recognition of its practical value, many opportunities, hitherto too often lost, have been taken advantage of. Latterly almost all special expeditions, whether despatched avowedly with the object of extending the boundaries of science, or for hydrographic purposes, or for training naval cadets, or for drilling the inmates of a penitentiary, or pioneering commercial enterprise, as in the case of Captain Wiggins's late excursions to the mouth of the Yenisei, have been supplied more or less fully with the means of scientific obser-

vation, and have been in many cases accompanied by observers trained in one department or another of physical research.

I will simply name among many such equipped and instructed expeditions of these later days, the splendid circumnavigating voyage of the Austrian frigate *Novara*, under the command of Admiral von Wullerstorf-Urbair (the report of the scientific results of this expedition has been published by the Austrian Government in eighteen beautifully illustrated volumes, and the completion of this work, after seventeen years of heavy labour, was one of the scientific events of the year 1877); the voyage of the Italian corvette *Magenta* round the world, so well chronicled by Professor Enrico Hillyer Giglioli; the very important sounding voyages of Captain Belknap, in the American surveying ship *Tuscarora*; the *Hassler* expedition, the last crowning effort with which the elder Agassiz closed a long and brilliant career devoted to the study and illustration of nature, and the many scientific explorations undertaken from year to year by the officers of the American Coast Survey, with the co-operation of the younger Agassiz and Count Pourtales; the tentative cruises of the British gunboats *Lightning* and *Porcupine*, culminating in the *Challenger* expedition; the scientific voyage round the world of the German frigate *Gazelle*; the several expeditions sent out by different Powers to observe the transit of Venus; the German Arctic expedition, under Captain Koldewey; the several Swedish expeditions, so rich in zoological results, to the Spitzbergen Sea, under the guidance of Otto Torell, Nordenskjöld, and others: the exhaustive researches into the conditions, physical and biological, of the North Sea by the North Sea Commission, under the direction of Dr. H. A. Meyer; the voyage of the *Tegethoff*, which Lieutenant Payer has rendered ever memorable by his thrilling story of disaster, success, and heroism; the Arctic voyage of the *Alert* and the *Discovery*, of which Sir George Nares has just published the semi-official narrative, a simple and charming account of almost superhuman effort and insuperable obstruction, which it is impossible to read without a feeling of regret that the devoted little band had attempted what was so hopeless, and at the same time a conviction that if their task had been practicable by human skill and bravery, it must certainly have been accomplished. But although this expedition of necessity failed in its main object, that of reaching the Pole, the additional information which we gain from Captain Nares's volume and from the more popular sketch of the voyage by Captain Markham on the physical condition of the Arctic Sea, is in the highest degree valuable. I must also mention the very important cruises in connection with the Norwegian Department of Fisheries, which, through the skilled labours of Professor Mohn and Professor G. O. Sars, annually contribute largely to our knowledge of the distribution of temperature, of the course of the ocean currents, and of the range of animal life in the North Atlantic. I observe in a letter from Professor Mohn, dated from Hammerfest on the 10th of last month, that the expedition of the past year has had a successful cruise to Bear Island, where it has left letters for the Dutch Arctic schooner, the *Willem Barentz*, and has made many important temperature observations. Professor Mohn speaks highly of the service rendered by Negretti and Zambra's new reversing thermometer. This is a most ingenious instrument, so constructed that by a simple mechanical arrangement the temperature may be registered at any given depth, irrespective of any number of zones of temperature, higher or lower, through which the instrument may have passed in descending. In the *Challenger* we felt greatly the want of such a thermometer, for although generally throughout the ocean the temperature of the water falls steadily from a surface maximum to a minimum at the bottom, in the Arctic and Antartic seas—where a special interest attaches to the vertical distribution of temperatures—the coldest layer is frequently, as in Professor Mohn's observations, on the surface; and a warmer belt intervenes between it and a bottom-stratum, probably, in many cases, of intermediate temperature. With the ordinary deep-sea registering thermometer, the temperature of the lowest layer cannot be ascertained with certainty. We had Negretti and Zambra's earlier instrument on the reversing principle on board during the latter part of our cruise, but through some defect in construction we did not find its indications trustworthy for great depths. I always believed the plan of construction of this instrument to be good,

and I am very glad to find from Professor Mohn's report that this defect has now been entirely overcome.

It follows from the nature of these many and varied enterprises that the department of geographical science to whose progress they have most specially contributed, is the physical geography of the sea; and the special appliances with which they have been provided have been principally instruments for determining the temperature of the water at different depths, the depth of the sea and the nature of the sea-bottom, and, in some few cases, the distribution of the deep-sea fauna. It is of course impossible for me in so short a time even to sketch their several lines of investigation, or to attempt to assign to each its share in the general advance of knowledge; I think it may be better that I should give an outline of some of the conditions of the regions to which they refer by the light of their combined results. I am aware that in taking this course I shall be forced to face questions on which there has been some controversy; and I can only say that I will avoid the controversial aspects of such questions as far as possible, and merely describe as shortly as I can the condition of things as they appear to me.

The General Ocean Circulation.—It was pointed out long ago by Sir Charles Lyell that many of the most marked phenomena of the present physical condition of the globe depend upon the fact that the surface of the world is divided into two hemispheres, one of which contains nearly the whole of the dry land of this world, while the other is almost entirely covered by water. The centre of the land-hemisphere is somewhere in Great Britain, and the centre of the water-hemisphere, which includes the southern sea, the South Pacific, whatever antarctic land there may be, Australia, and the southern point of South America, is in the neighbourhood of New Zealand. With a full knowledge of the absolute continuity of the ocean, we have hitherto been too much in the habit of regarding it as composed of several oceans, each possibly under special physical conditions. All recent observations have, however, shown us that the vast expanse of water which has its centre in the southern hemisphere, is the one great ocean of the world, of which the Atlantic, with the Arctic Sea and the North Pacific, are merely northward extending gulfs; and that any physical phenomena affecting obviously one portion of its area must be regarded as one of an interdependent system of phenomena affecting the ocean as a whole.

Shallow as the stratum of water forming the ocean is—a mere film in proportion to the radius of the earth—it is very definitely split up into two layers, which, so far as all questions concerning ocean movements and the distribution of temperature is concerned, are under very different conditions. At a depth varying in different parts of the world, but averaging perhaps 500 fathoms, we arrive at a layer of water at a temperature of 40° F., and this may be regarded as a kind of neutral band separating the two layers. Above this band, the temperature varies greatly over different areas, the isothermobathic lines being sometimes tolerably equally distributed, and at other times crowding together towards the surface; while beneath it, the temperature almost universally sinks very slowly and with increasing slowness to a minimum at the bottom.

The causes of natural phenomena, such as the movements of great masses of water, or the existence over large areas of abnormal temperature conditions, are always more or less complex, but in almost all cases one cause appears to be so very much the most efficient that in taking a general view all others may be practically disregarded; and speaking in this sense it may be said that the trade-winds and their modifications and counter-currents are the cause of all movements in the stratum of the ocean above the neutral layer. This system of horizontal circulation, although so enormously important in its influences upon the distribution of climate, is sufficiently simple. Disregarding minor details, the great equatorial current driven from east to west across the northerly extensions of the ocean by the trade-winds, impinges upon the eastern coasts of the continents. A branch turns northwards and circles round the closed end of the Pacific, tending to curl back to the North American coast from its excess of initial velocity; and in the Atlantic, following a corresponding course, the Gulf Stream bathes the shores of northern Europe, and a branch of it forces its way into the Arctic basin, and bat-

tling against the palæocrystic ice, keeps imperfectly open the water-way by which Nordenskjöld hopes to work his course to Behring's Strait. The southern deflections are practically lost, being to a great extent, though not entirely, dissipated in the great westerly current of the southern anti-trades.

One of the most singular results of these later investigations is the establishment of the fact that all the vast mass of water, often upwards of 2000 fathoms in thickness, below the neutral band, is moving slowly to the northward; that in fact the depths of the Atlantic, the Pacific, and the Indian Oceans are occupied by tongues of the Antartic Sea, preserving in the main its characteristic temperatures. The maintenance of a low temperature while the temperature of the floor of the ocean must be higher, and that of the upper layers of the sea greatly higher, is in itself a conclusive proof of steady movement of the water from a cold source; and the fact that the temperature of the lower layers of water, both in the Atlantic and the Pacific, is slightly but perceptibly raised to the northward, while the continuity of every layer with a corresponding layer in the southern sea can be clearly traced, indicates the southern position of that source.

The immediate explanation of this very unexpected phenomenon seems simple. From some cause or other, as yet not fully understood, evaporation is greatly in excess of precipitation over the northern portion of the land-hemisphere, while over the water-hemisphere, and particularly over its southern portion, the reverse is the case; thus one part of the general circulation of the ocean is carried on through the atmosphere, the water being raised in vapour in the northern hemisphere, hurried by upper wind currents to the zone of low barometric pressure in the south, where it is precipitated in the form of snow or rain, and, welling thence northwards in the deepest channels on account of the high specific gravity dependent on its low temperature, supplies the place of the water which has been removed.

The cold water wells northwards, but it meets with some obstructions on its way, and these obstructions, while they prove the northward movement, if further proof were needed, bring out another law by which the distribution of ocean temperature is regulated. The deeper water sinks slowly to a minimum at the bottom, so that if we suppose the temperature at a depth of 2000 fathoms to be 36° F., the temperature at a depth of 3000 may be, say, 32°. Now, if in this case the slow current meet on its northward path a continuous barrier in the form of a submarine mountain ridge rising to within 2000 fathoms of the sea-surface, it is clear that all the water below a temperature of 36° will be arrested, and, however deep the basin beyond the ridge may be, the water will maintain a minimum of 36° from a depth of 2000 fathoms to the bottom. In many parts of the ocean we have most remarkable examples of the effect upon deep-sea temperature of such barriers intersecting cold in-draughts, the most marked instance, perhaps, a singular chain of closed seas at different temperatures among the islands of the Malay Archipelago; but we have also a striking instance nearer home. Evaporation is greatly in excess of precipitation over the area of the Mediterranean, and consequently, in order to keep up the supply of water to the Mediterranean, there is a constant inward current through the Straits of Gibraltar from the Atlantic; I need not at present refer to an occasional tidal counter-current. The minimum temperature of the Mediterranean is about 54° F. from a depth of 100 fathoms to the bottom. The temperature of 54° is reached in the Atlantic at the mouth of the Straits of Gibraltar at a depth of about 100 fathoms, so that in all probability future soundings will show that the free water-way through the Straits does not greatly exceed 100 fathoms in depth.

The Depth of the Sea, and the Nature of Modern Deposits.—It seems now to be thoroughly established by lines of trustworthy soundings which have been run in all directions, that the average depth of the ocean is a little over 2000 fathoms, and that in all probability it nowhere exceeds 5000 fathoms. Depths beyond 4000 fathoms are rare and very local, and seem to be usually pits in the neighbourhood of volcanic islands. In all the ocean basins there are depressions extending over considerable areas where the depth reaches 3000 fathoms or a little more, and these depressions maintain a certain parallelism with the axes of the neighbouring continents.

Within 300 or 400 miles of the shore, whether in deep or in shallow water, formations are being laid down, whose materials are derived mainly from the disintegration of shore rocks, and which consequently depend for their structure and composition upon the nature and composition of the rocks which supply their materials. These deposits imbed the hard parts of the animals living on their area of deposition, and they correspond in every way with sedimentary formations with which we are familiar, of every age. In water of medium depths down to about 2000 fathoms, we have in most seas a deposit of the now well-known globigerina-ooze, formed almost entirely of the shells of Foraminifera living on the sea surface, and which after death have sunk to the bottom. This formation, which occupies a large part of the bed of the Atlantic and a considerable part of that of the Pacific and Southern Seas, is very like chalk in most respects, although we are now satisfied that it is being laid down as a rule in deeper water than the chalk of the Cretaceous period.

In depths beyond 2500 or 3000 fathoms no such accumulations are taking place. The shores of continents are usually too distant to supply land detritus, and although the chalk-building Foraminifera are as abundant on the surface as they are elsewhere, not a shell reaches the bottom; the carbonate of lime is entirely dissolved by the carbonic acid contained in the water during the long descent of the shells from the surface. It therefore becomes a matter of very great interest to determine what processes are going on, and what kind of formations are being laid down in these abyssal regions, which must at present occupy an area of not less than ten millions of square miles.

The tube of the sounding instrument comes up from such abysses filled with an extremely fine reddish clay, in great part amorphous, but containing, when examined under the microscope, a quantity of distinctly recognisable particles, organic and inorganic. The organic particles are chiefly siliceous, and for the most part the shells or spines of Radiolarians which are living abundantly on the surface of the sea, and apparently in more or less abundance at all depths. The inorganic particles are minute flakes of disintegrated pumice, and small crystalline fragments of volcanic minerals; the amorphous residue is probably principally due to the decomposition of volcanic products, and partly to the ultimate inorganic residue of decomposed organisms. There is ample evidence that this abyssal deposit is taking place with extreme slowness. Over its whole area, and more particularly in the deep water of the Pacific, the dredge or trawl brings up in large numbers nodules very irregular in shape, consisting chiefly of peroxide of iron and peroxide of manganese, deposited in concentric layers in a matrix of clay, round a nucleus formed of a shark's tooth, or a piece of bone, or an otolith, or a piece of siliceous sponge, or more frequently a fragment of pumice. These nodules are evidently formed in the clay, and the formation of the larger ones and the segregation of their material must have taken a very long time. Many of the sharks' teeth to which I have alluded as forming the nuclei of the nodules, and which are frequently brought up uncoated with foreign matter, belong to species which we have every reason to believe to be extinct. Some teeth of a species of *Carcharodon* are of enormous size, four inches across the base, and are scarcely distinguishable from the huge teeth from the tertiary beds of Malta. It is evident that these semi-fossil teeth, from their being caught up in numbers by the loaded line of the trawl, are covered by only a very thin layer of clay.

Another element in the red clay has caused great speculation and interest. If a magnet be drawn through a quantity of the fine clay well diffused in water, it will be found to have caught on its surface some very minute magnetic spherules, some apparently of metallic iron in a passive state, and some of metallic nickel. From the appearance of these particles, and from the circumstance that such magnetic dust has been already detected in the sediment of snow-water, my colleague, Mr. Murray, has a very strong opinion that they are of cosmic origin—excessively minute meteorites. They certainly resemble very closely the fine granules which frequently roughen the surface of the characteristic skin of metorites, and from their composition and the circumstances under which they are found, there is much to be said in favour of this view. I cannot, however, hold it entirely

proved; there can be little doubt, from the universal presence of water-logged and partially decomposed pumice on the bottom, and from the constant occurrence of particles of volcanic minerals in the clay, that the red clay is formed in a great measure by the decomposition of the lighter products of submarine volcanoes drifted about by currents, and finally becoming saturated with water and sinking; and it is well known that both iron and nickel in a metallic state are frequently present in minute quantities in igneous rocks. I think it is conceivable that the metallic spherules may be derived from this source.

So far as we can judge, after a most careful comparative examination, the deposit which is at present being formed at extreme depths in the ocean, does not correspond either in structure or in chemical composition with any known geological formation; and, moreover, we are inclined to believe, from a consideration of their structure and of their imbedded organic remains, that none of the older formations were laid down at nearly so great depths—that, in fact, none of these have anything of an abyssal character. These late researches tend to show that during past geological changes abyssal beds have never been exposed, and it seems highly probable that until comparatively recent geological periods such beds have not been formed.

It appears now to be a very generally received opinion among geologists—an opinion which was first brought into prominence by Professor Dana—that the "massive" eruptions which originated the mountain chains which form the skeleton of our present continents, and the depressions occupied by our present seas, date from the secular cooling and contraction of the crust of the earth, from a period much more remote than the deposition of the earliest of the fossiliferous rocks; and that during the period chronicled by the successive sedimentary systems, with many minor oscillations by which limited areas have been alternately elevated and depressed, the broad result has been the growth by successive steps of the original mountain chains and the extension of the continents by their denudation, and the corresponding deepening of the original grooves. If this view be correct—and it certainly appears to me that the reasoning in its favour is very cogent—it is quite possible that until comparatively recent times no part of the ocean was sufficiently deep for the formation of a characteristic abyssal deposit.

Time will not allow me even to allude to the interesting results which have been obtained from the determination of the density of sea water from different localities and different depths, and from the analysis of sea water, and its contained gases, and perhaps these results have been scarcely sufficiently worked out as yet to afford safe bases for generalization. I must, however, say a few words as to certain additions which have been made to our knowledge of the two hitherto impregnable strongholds of the frost, the regions round the North and South Poles.

The Arctic Regions.—The question which has of late held the most prominent place in all discussions about the conditions of the Arctic Regions, particularly since the voyage of Dr. Hayes, is whether it is possible that there can be at all times or at any time anything in the form of an open Polar sea. This question seems now to be virtually settled, and in the most unsatisfactory manner imaginable. There can be no doubt that in the year 1871, Count Wilczek in the schooner *Isbjorn* found the sea between Novaya Zemlya and Spitzbergen nearly free from ice, and that the same sea presented to Weyprecht and Payer in the following year a dangerous stretch of moving and impenetrable pack. There can be no doubt that in the year 1861 Dr. Hayes gazed over an expanse of open water where in 1875–6 Captain Nares studied the conditions of palæocrystic ice. It is evident therefore that the Polar basin, or at all events such portions of it as have been hitherto reached, is neither open sea nor continuous ice, but a fatal compromise between the two, an enormously heavy pack formed by the piling up and crushing together of the floe of successive years, in frequent movement, breaking up and shifting according to the prevailing direction of the wind, and leaving open, now here and now there, lanes and vistas of deceptive open water, which may be at any moment closed and converted into a chaotic mass of hurtling floe-bergs by a hurricane from another direction. It seems, however, that in certain seasons

there is more open water in the direction of Grinnell's Land and Smith's Sound than in others, and that there are also years comparatively favourable for the northward route following the lead of Franz-Josef Land; and there seem now to be only two plans, one nearly as hopeless as the other, to chose between in any future attempt—either to establish several permanent Polar stations, as proposed by Lieut. Weyprecht, and already initiated at one point, so far as preliminaries are concerned, by Captain Tyson and Captain Howgate, and to seize the opportunity of running north in early autumn from the station where the sea appears most open; or to run as far north as possible at enormous expense, with a great force of men and abundance of provisions and paraffin oil, and push northwards during the arctic winter by a chain of communicating stations with ice-built refuge huts. It seems possible that in a cold season, with the pack in the condition in which Markham found it in 1876, some progress might be made in this way, if it were conceivable that the end to be gained was worth the expenditure of so much labour and treasure.

The Antarctic Regions.—But little progress has been made during the last quarter of a century in the actual investigation of the conditions of that vast region which lies within the parallel of 70° S. Some additional knowledge has been acquired, and the light which recent inquiries have thrown upon the general plan of ocean circulation and the physical properties of ice, have given a new direction to what must partake for some time to come of the nature of speculation.

From information derived from all sources up to the present time, it may be gathered that the unpenetrated area of about 4,700,000 square miles surrounding the South Pole is by no means certainly a continuous "Antarctic continent," but that it consists much more probably partly of comparatively low continental land, and partly of a congeries of continental (not oceanic) islands, bridged between and combined, and covered to the depth of about 1400 feet, by a continuous ice-cap: with here and there somewhat elevated continental chains, such as the groups of land between 55° and 95° W., including Peter the Great Island and Alexander Land, discovered by Billingshausen in 1821, Graham Land and Adelaide Island, discovered by Biscol in 1832, and Louis Philippe Land by D'Urville in 1838, and at least one majestic modern volcanic range discovered by Ross in 1841 and 1842, stretching from Balleny Island to a latitude of 78° S., and rising to a height of 15,000 feet. It seems, so far as is at present known, that the whole of the antarctic land, low and high, as well as the ice-cap of which a portion of the continuous continent may consist, is bordered to some distance by a fringe of ice, which is bounded to seaward by a perpendicular ice-cliff, averaging 230 feet in height above the sea-level. Outside the cliff a *floe*, which attains near the barrier a thickness of about 20 feet and in some places, by piling a considerably greater thickness, extends northwards in winter to a distance varying according to its position with reference to the southward-trending branches of the equatorial current; and this floe is replaced in summer by a heavy drifting pack with scattered ice-bergs. Navigating the Antarctic Sea in the southern summer, the only season when such navigation is possible, it has been the opinion of almost all explorers, that after forcing a passage through an outer belt of a heavy pack and ice-bergs, moving as a rule to the north-westward, and thus fanning out from the ice-cliff in obedience to the prevailing south-easterly winds, a band of comparatively clear water is to be found within.

Several considerations appear to me to be in favour of the view that the area round the South Pole is broken up and not continuous land. For example, if we look at a general ice-chart we find that the sea is comparatively free from ice-bergs, and that the deepest notches occur in the "Antarctic Continent" at three points, each a little to the eastward of south of one of the great land masses. Opposite each of these notches a branch of the equatorial current is deflected southwards by the land, and is almost merged in the great drift-current which sweeps round the world in the Southern Sea before the westerly anti-trades. But while the greater portion of the Brazilian current, the East Australian current, and the southern part of the Agulhas current, are thus merged, they are not entirely lost;

for at these points of junction with the drift-current of the westerlies, the isobathytherms are slightly deflected to the southwards, and it is opposite these points of junction that we have comparatively open sea and penetrable notches in the southern pack. But we have not only the presumed *effect* of this transfer of warmer water to the southwards, we were able to detect its presence in the *Challenger* by the thermometer. Referring to the result of a serial temperature sounding on the 14th of February 1874, with a surface temperature of 29° F. at a depth of from 300 to 400 fathoms, there is a band of water at a temperature more than half a degree above the freezing-point, That this comparatively warm water is coming from the north there is ample proof. We traced its continuity with a band at the same depth gradually increasing in warmth to the northward, and it is evident that its heat can be derived from no other source, and that it must be continually receiving new supplies, for it is overlaid by a band of colder water, tending to mix with it by convection.

It is, of course, possible that these warm currents may by coincidence be directed towards those notches already existing in a continental mass of land; but such a coincidence would be remarkable, and there is certainly a suggestion of the alternative that the "continent" may consist to so great an extent of ice as to be liable to have its outline affected by warm currents.

In high southern latitudes it seems that all the icebergs are originally tabular, the surface perfectly level and parallel with the surface of the sea, a cliff about 230 feet high bounding the berg. The top is covered with a layer of the whitest snow; now and then a small flock of petrels take up their quarters upon it, and trample the soil some few square yards, but after their departure one of the frequent snow showers restores it in a few minutes to its virgin whiteness. The upper part of the cliff is pale blue, which gradually deepens towards the base. When looked at closely, the face of the cliff is seen to be traversed by a delicate ruling of faint blue lines, the lines being more distant from one another above and becoming gradually closer. The distance between the well-marked lines near the top of a berg may be of a foot or even more, while near the surface of the water it is not more than two or three inches, and the space between the blue lines have lost their dead whiteness and have become hyaline or bluish. The blue lines are very unequal in their strength and in their depth of colouring; sometimes a group of very dark lines gives a marked character to a part of a berg. Between the stronger blue lines near the top of the cliff a system of closer lines may be observed, marking the division of the ice by still finer planes of lamination; but in the narrower spaces near the water-line they are blended and lost. The blue lines are the sections of sheets of clear ice; the white intervening bands are the sections of layers of ice where the particles are not in such close contact—ice probably containing some air.

The stratification in all these icebergs is, I believe, originally horizontal and conformable, or very nearly so. In many, while melting and beating about in the sea, the strata become inclined at various angles, or vertical or even reversed; in many they are traversed by faults, or twisted, or contorted, or displaced; but I believe that all deviations from a horizontal arrangement are due to changes taking place in the icebergs themselves.

I think there can be no doubt, from their shape and form, and their remarkable uniformity of character, that these great table-topped icebergs are prismatic blocks riven from the edge of the great antarctic ice-sheet. I conclude, therefore, that the upper part of the iceberg, including by far the greater part of its bulk, and culminating in the portion exposed above the surface of the sea, was formed by the piling up of successive layers of snow during the period, amounting perhaps to centuries, during which the ice-cap was slowly forcing its way over the low-land, and out to sea over a long extent of gentle slope, until it reached a depth considerably beyond 200 fathoms, when the lower specific weight of the ice caused an upward strain which at length overcame the cohesion of the mass, and portions were rent off and floated away. The icebergs when they are first dispersed float in from 200 to 250 fathoms; when, therefore, they have been drifted to latitudes of 65° or 64° south, the bottom of the berg, the surface which forced itself glacier-

like over the land, just reaches the layer at which the temperature of the water distinctly rises; and is rapidly melted, and the pebbles and land *débris* with which it is more or less charged are precipitated. That this precipitation takes place all over the area where the icebergs are breaking up, constantly and to a considerable extent, is evident from the fact that the matter brought up by the sounding instrument and the dredge is almost entirely composed of such deposits from ice; for Diatoms, Foraminifera, and Radiolarians are present on the surface in large numbers, and unless the deposit from the ice were abundant it would soon be covered and masked by the skeletons of surface organisms.

The curious question now arises, what is the cause of the uniform height of the southern icebergs,—that is to say, what is the cause of the restriction of the thickness of the free edge of the ice-cap to 1400 feet? I have mentioned the gradual diminution in thickness of the strata of ice in a berg from above downwards. The regularity of this diminution leaves it almost without a doubt that the layers observed are in the same category, and that therefore the diminution is due to subsequent pressure or other action upon a series of beds, which were at the time of their deposition nearly equally thick. About sixty or eighty feet from the top of an iceberg, the strata of ice a foot or so in thickness, although of a white colour, and thus indicating that they contain a considerable quantity of air, are very hard, and the specific weight of the ice is not much lower than that of layers three inches thick nearer the water-line of the berg. The upper layers have been manifestly produced by falls of snow after the berg has been detached.

Now, it seems to me that the reduction in thickness cannot be due to compression alone, but that a portion of the substance of the lower layers must have been removed. It is not easy to see why the temperature of the earth's crust, under a widely extended and practically permanent ice-sheet of great thickness, should ever fall below the freezing-point; and it is a matter of observation that at all seasons of the year vast rivers of muddy water flow into the frozen sea from beneath the great glaciers which are the issues of the ice-sheet of Greenland. Ice is a very bad conductor, so that the cold of winter cannot penetrate to any great depth into the mass. The normal temperature of the surface of the earth's crust, at any point where it is uninfluenced by cyclical changes, is at all events above the freezing-point, so that the temperature of the floor of the ice-sheet would certainly have no tendency to fall below that of the stream passing over it. The pressure upon the deeper beds of the ice must be enormous at the bottom of an ice-sheet 1400 feet in thickness—not much less than a quarter of a ton on the square inch. It seems, therefore, probable that under the pressure to which the body of ice is subjected, a constant system of melting and regelation is taking place, the water passing down by gravitation from layer to layer until it reaches the floor of the ice-sheet, and finally working out channels for itself between the ice and the land, whether the latter be subaërial or submerged.

I should think it probable that this process, or some modification of it, may be the provision by which the indefinite accumulation of ice over the antarctic continent is prevented, and a certain uniformity in the thickness of the ice-sheet maintained—that in fact ice at the temperature at which it is in contact with the surface of the earth's crust within the antarctic regions cannot support a column of itself more than 1400 feet high without melting. It is suggested to me by Professor Tait that the thickness of the ice-sheet very probably depends upon its area, as the amount of melting through squeezing and the earth's internal heat will depend upon the facility of the escape of the water. The problem is, however, an exceedingly complex one, and we have perhaps scarcely sufficient data for working it out.

The Fauna of the Deep Sea.—I can scarcely regret that it is utterly impossible for me on this occasion to enter into any details with regard to the relations of the abyssal fauna, the department of the subject which has naturally had for me the greatest interest. Recent investigations have shown that there is no depth limit to the distribution of any group of gill-bearing marine animals. Fishes, which from their structure and from what we know of the habits of their congeners must certainly live on the bottom, have come up from all depths, and at all depths the

whole of the marine invertebrate classes are more or less fully represented. The abyssal fauna is of a somewhat special character, differing from the fauna of shallower water in the relative proportions in which the different invertebrate types are represented. It is very uniform over an enormously extended area, and in this respect it fully confirms the anticipations of the great Scandinavian naturalist Lovén, communicated to this Association in the year 1844. It is a rich fauna, including many special genera, and an enormous number of special species, of which we, of course, know as yet only a fraction; but I do not think I am going too far in saying that from the results of the *Challenger* expedition alone the number of known species in certain classes will be doubled. The relations of the abyssal fauna to the faunæ of the older Tertiary and the newer Mesozoic periods are much closer than are those of the faunæ of shallow water; I must admit, however, that these relations are not so close as I expected them to be,—that hitherto we have found living only a very few representatives of groups which had been supposed to be extinct. I feel, however, that until the zoological results of several of these later voyages, and especially those of the *Challenger*, shall have been fully worked out, it would be premature to commit myself to any generalisations.

I have thus attempted to give a brief outline of certain defensible general conclusions, based upon the results of recent research. Some years ago, certain commercial enterprises, involving the laying of telegraph cables over the bed of the sea, proved that the extreme depths of the ocean were not inaccessible. This somewhat unexpected experience soon resulted in many attempts, on the part of those interested in the extension of the boundaries of knowledge, to use what machinery they then possessed to determine the condition of the hitherto unknown region. This first step was naturally followed by a development of all appliances and methods bearing upon the special line of research; and within the last decade the advance of knowledge on all matters bearing upon the physical geography of the sea has been confusingly rapid—so much so, that at this moment the accumulation of new material has far outstripped the power of combining and digesting and methodising it. This difficulty is greatly increased by the extreme complexity of the questions, both physical and biological, which have arisen. Steady progress is, however, being made in both directions, and I trust that in a few years our ideas as to the condition of the depth of the sea may be as definite as they are with regard to regions to which we have long had ready access.

The following Papers were read :—

1. *A Journey on Foot through Arabia Petræa. By the* Rev. F. W. HOLLAND, *M.A., F.R.G.S.*

The objects of this expedition were—

1. To examine the sandstone district in the Peninsula of Sinai lying between the ancient Egyptian mining stations of Wady Mughârah and Serâbit el Kâdim, with the view of the possible discovery of further Egyptian ruins or inscriptions.

2. To trace out the various routes that the children of Israel might have taken on their journey northwards from Mount Sinai (Jebel Mûsa) to Kadesh Barnea, so as to institute a just comparison between the facilities or difficulties which attended them.

3. To explore Jebel Mugrâh and Ain Kadeis, in the hopes of throwing some additional light upon the disputed questions of the site of Kadesh Barnea and the boundary of the ancient kingdom of Edom.

4. To follow the road from Wady el Arish by the ancient Lake Serbonis to Kantara, this having been suggested by Brugsch Bey as the route taken by the children of Israel when they left Egypt.

Starting from Suez on March 31st, attended only by three Arabs of the Jowârah tribe, Mr. Holland made a walking tour to Jebel Mûsa, which he believed to be

the true Mount Sinai; thence northwards by Wadies Telleger and El Atujeh, by the route followed by Baron Koller in 1840 ('R. G. S. Journal,' 1842) to Wady el Hessi; thence N.W. to Nakhl, and so on by Wady Muweilah to Wady el Ain. Leaving his Jowârah Arabs at Wady el Ain, he took an escort of the Haiwât tribe and made an expedition up Wady Kadeis, and eastwards across Jebel Mugrâh, returning by Wady Lussan. On leaving Wady el Ain, he followed down Wady Muweilah to Wady el Arith, and passing south of Jebel Helal, and north of Jebel Yelek. he crossed Jebel Mughârah, and, striking due west, arrived at Ismailia on May 23rd.

The results of the journey were as follows:—

1. Mr. Holland found extensive turquoise mines worked by the Arabs between Wady Mughârah and Wady Nusb, but no further Egyptian ruins or inscriptions. He traced out and mapped the course of Wady Sahone, an important valley, which had previously been unexplored, and found that it forms the upper portion of Wady Shellâh, which takes its name, 'the valley of cataracts,' from the water, which flows down it after rain, falling over a cliff. He also explored the ancient turquoise mines of Serâbit el Kâdim, and ascended Jebel Umen Riglain.

2. On leaving Jebel Mûsa he journeyed north-east to the neighbourhood of Ain el Huthera, which has been identified with Hazeroth. Mr. Holland cannot agree with this identification, nor does he believe it possible for the large host of the Israelites to have travelled this way. Following up the course of Wady Marah, he reached Ain el Akhdar. Thence he explored the passes of Jebel Thellah and the plateau of Zeranîk, and afterwards descended Wady Zelleger, Wadies Edeid and Biyâr, and the pass of El Mirad. He finally came to the conclusion that the only available route for the children of Israel to have taken was that by Wadies Zelleger and El Atiyeh. These valleys afford the most direct, the best watered, and by far the most easy course from Jebel Mûsa northwards, and by them one ascends to the plateau of the desert of Et Tîh without any difficult pass. The want of water and Arab raids compelled him to give up his plan of travelling northwards direct to Jebel Mugrâh; but he passed over the water-shed of Jebel et Tîh, into the open plateau on the north, and made a route survey of that portion of the country which would present the greatest difficulties to the passage of a large host. In his journey to Nakhl from the head of Wady Atîyeh, he also passed across a district that had been previously unexplored.

3. Jebel Mugrâh had in the author's belief never before been penetrated by travellers, and he found that its position on the maps was far from correct. He carefully explored Wady Kadies, and came to the conclusion that its position militates strongly against its identification with Kadesh Barnea. Jebel Mugrâh belongs to the territory of the Haiwât Arabs, and not to that of the Azazimeh as has generally been stated. It shows traces of ancient habitation and cultivation, and extends eastwards only about as far as lat. 35°: here it ends abruptly in a steep cliff, and is separated from Jebel Jerâfeh by the head of Wady Garaiyeh and Wady Jerâfeh. These valleys he believed to afford the road which was known as "the way of the spies," and formed the western boundary of Edom. Kadesh Barnea he would place at the south-east point of Jebel Mugrâh, but he was unable to descend into the plain.

4. Mr. Holland gave up his intention of following down Wady el Arish to the coast from Wady Muweilah, both because the bed of the Wady proved a very bad road for travelling, and also because he heard from the Arabs of a direct road westwards to Ismailia, which appeared a very important one to explore. It was not marked on any map seen, but was described by the Arabs as an easy, direct, and well-watered route to Egypt, a description found to be perfectly correct. The course of Wady el Arish has been very inaccurately laid down. It runs to the east of Jebel Helal, and passes through that mountain by a narrow gorge. Jebel Yelek has been placed too far to the north. Wady Hasanah, which contains three wells, and is a very important watering-place, runs to the west of Jebel Helah. After crossing Wady Hasanah and passing to the north of Jebel Yelek, the road crosses Jebel Mughârah, an important range, where there are wells and ancient ruins, and then, turning due west, runs over a rolling plateau, in places much covered

with sand-drifts, to Ismailia. Large numbers of flint flakes and arrow-heads prove that this road was much used in ancient times, and there can be little doubt that it was the road followed by Abraham from the Negeb, or south country, to Egypt. Large tracts of land on the west of Jebel Mughârah are cultivated by the Arabs. The discovery of this road is regarded as one of great importance, and, as far as the author can learn, it has been previously unknown.

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2. *Survey of Galilee.* *By* Lieut. H. H. Kitchener, *R.E.*, *F.R.G.S.*

This paper contained an account of the operations subsequent to those described by Major Wilson at the last meeting of the Association.

On the renewal of the survey, Lieut. Kitchener found that the cairns built at Hattin in 1875 were all destroyed; but after a careful search he found the broad arrows cut on the rock under where the cairns had been, and was thus able to carry on the triangulation from a base of 25 miles, and other calculated lines from 8 to 12 miles long; subsequently, after carrying the triangulation round the country, the calculated length of this base was only 60 feet different from the measurement started with, or a little more than 2 feet of possible error in the mile. On the scale employed, this error in 25 miles is only the thickness of a pencil line.

The triangulation took eight days from this camp, as the old cairns had to be rebuilt, and new ones erected in the northern country. By thus doing the triangulation and survey of the ground from each camp were both kept going together, and the strength of the party was not sufficient to adopt any other method. While observing from the top of Mount Tabor, Lieut. Kitchener examined three chapels recently unearthed by the Roman Catholic monks; they date from crusading times, when this was supposed to be the Mount of the Transfiguration, and the three chapels are mentioned in old chronicles of that time.

Immediately above the camp was an extinct volcano, called the Kurn Hattin, or Horns of Hattin, being two peaks on the top of a steep mountain, having between them the crater of an extinct volcano, memorable as the scene of the final struggle of the Crusaders after the fatal battle on the plain below.

On the completion of the triangulation, the levelling had to be taken up from the last point on the line. In seven days' work $16\frac{1}{4}$ miles were accomplished, and the seashore was reached, giving a depression of 682 feet 6 inches below the Mediterranean.

The survey of the detail had then to be done. From the fixed triangulation-points a number of supplementary angles were taken to every village, hill-top, prominent tree, or important object in view; and, as this was done from every point, when these lines were plotted, intersections fixing these objects were obtained. Practically almost every place of importance was fixed in this way. The surveyor then started with this diagram of fixed points, and by the interpolation of the angles taken with his prismatic compass was able to fix his own position at any point on paper; he then sketched in by eye the detail that was in his close vicinity, and by going through the same process all over his work, the detail was obtained with considerable accuracy. The heights of all places of importance were taken by aneroids, besides the calculated heights of all the triangulation-points. These aneroids were checked morning and evening with a standard barometer kept in camp. The slopes of the hills were taken by Abney's level, and on returning to camp in the evening a report was made of all ruins, villages, and water-supply in the work of the day. The nomenclature was written down in Arabic by a well-educated scribe kept for that purpose. Each surveyor had a guide with him, who gave the names of the different places. The surveyor wrote them down as near as he could to the sound, and on returning to camp he repeated them in front of the guide and the scribe. The guide then pronounced the names correctly, and the scribe wrote it down from him. Lieut. Kitchener afterwards transliterated the Arabic in accordance with Robinson's method, and the proper spelling was thus

obtained, and written on the map. Every possible check on the veracity of the natives was employed by asking the names of numbers of people independently.

One of the great values of the resulting map is the number of unknown names it has made public; thus, on this survey, 2770 names were collected, only about 450 of which were to be found on the best formerly existing map of the country. Another is the accuracy of these names, taken down from the natives in a manner never attempted before; and the result has been to throw a vast light on the ancient nomenclature of the country, and the origin of the races that inhabit it.

The survey of the detail took five more days, and on the 27th March the camp was moved to Tiberias, with the assurance of having no obstacle of a technical nature to hinder work.

The scenery of the lake is decidedly monotonous, but there is a great charm in that dry and thirsty land in having a vast expanse of fresh water spread out before the eyes. During the survey of the shores, a considerable discovery was made, viz., the site of Sennabris, mentioned by Josephus as the place where Vespasian pitched his camp when marching on the insurgents of Tiberias. The name Sinn en Nabra still exists, and is well known to the natives; it applies to a ruin situated on a spur from the hills that close the southern end of the Sea of Galilee; it formed, therefore, the defence against an invader from the Jordan plain, and blocked the great main road in the valley.

Close beside it, there is a large artificially-formed plateau, defended by a water-ditch on the south, communicating with Jordan, and by the Sea of Galilee on the north. This is called Kh. el Kerâk, and is doubtless the remains of Vespasian's camp described by Josephus. It is just like another Roman camp found near Jenin, where an army was camped. This Kh. el Kerâk has been identified with Tarichæa, but, as Major Wilson has pointed out, that site must be sought to the north of Tiberias. The finding of Sennabris, the place where the Roman host encamped before marching on Tiberias and Tarichæa, clearly proves that the latter place could not have been anywhere near the southern end of the lake.

The ruins of ancient Tiberias, with its sea-walls and scattered columns, extend nearly as far south as these springs, and it may be fairly supposed that the modern site of the town is situated to the north of the ancient place.

Passing the ruin of Kuneitriâh, where, Lieut. Kitchener believes, the ancient Tarichæa was situated, and the plain beyond, the path leads along the side of the steep slope of the hills, with rocky cliffs towering above, and the sea almost directly below; turning a corner, the Plain of Gennesareth lies spread out, with the cluster of ruined hovels of the village of Mejdel in the foreground. A fine stream of water irrigates this portion of the plain from Wady Hamam, the narrow gorge through which the levelling had been brought down, with cliffs 1000 feet high on either side. In those on the south, are the caves of the robbers who were subdued by Herod the Great by letting down soldiers on platforms from above on the defenders, who slew one another sooner than be taken captive. Lieut. Kitchener explored the caves, which consist of galleries at different heights conducted along the face of the precipice leading to different-sized chambers; some appeared natural, while others were artificial; there were spacious halls, small sleeping-places, and some enormous stables, all cut out of the solid rock. Water was brought by a long aqueduct, cut in the face of the precipice, and poured down into cisterns inside the fortress. The place has been since occupied by Arab marauders, who have built walls to defend the outside of the galleries and round towers at different elevations on the face of the rock, to bring a flanking fire on the entrance, which was reached by a long flight of basalt steps.

Beyond Mejdel on the Plain of Gennesareth, and round the northern shores of the lake, are the most interesting sites of all—Capernaum, Chorazin, and Bethsaida. Lieut. Kitchener does not agree with Major Wilson in the position of Capernaum at Tell Hum, but would rather place it at Kh. Minia on the plain, believing the fine remains of Tell Hum to be the relics of the known grandeur of the ancient Bethsaida.

On the 4th April the camp was moved to Khân Jubb Yusef, situated on the great Damascus road, and some distance from any inhabited village. The country

round is occupied by wandering tribes of Bedouin Arabs with their goat flocks; to the east it is a mass of basalt which has flowed over the country, and down to the shores of the lake; to the west are the limestone hills of Safed.

From the subsequent camp at Meiron, the triangulation required a considerable amount of attention. The Jebel Jermûk, the highest peak in Galilee, reaching an altitude of 3930 feet, had been observed from the south, but now it was necessary to ascend and observe from it; this was accomplished, and the triangulation thrown well forward to the north, but the triangulation would not allow of a descent to the low unhealthy Huleh marshes as early as had been hoped. The village of Meiron is a famous Jewish place of pilgrimage, for there Rabbi Shamai and Hillel and the Great Simeon Ben Jochai lie buried. The rocks around are honeycombed with ancient tombs, and there still remains an almost perfect *façade* of an ancient synagogue, dating probably from the second century after Christ. The principal results of the survey of this district were the discovery of three dolmens. During the course of the survey, eight dolmens were discovered, and as these are the first that have been noted in Palestine, it adds a new district to those already known to possess these rude stone monuments, and may be a connecting link between the ancient inhabitants of Europe and India.

The remains of two synagogues, unobserved hitherto, were discovered, one at Sŭfsâf and the other at El Jish. These add considerably to our knowledge of these interesting buildings, and the discovery of the Roman eagle engraved in relief in the synagogue of El Jish adds new proof that these buildings are due to Roman influence over a subjugated people. The eleven specimens that remain of these buildings were carefully examined and planned during the course of the survey where it was possible to trace the original work.

The triangulation and survey of the country round Dibl, to which the camp moved on May 3rd, took twelve days; a number of curious ruins were visited, and special plans and photographs were made. The country to the west was rugged and rocky, covered with brush-wood, and occupied by Arab tribes. Deep ravines and gorges carried the winter rains down to the sea, and in many parts of this wild country a European had never before been seen. To the east, the country was more open and cultivated; there are not many springs, but numbers of rock-cut cisterns and large pools for collecting the winter rains at almost every village.

On the 16th, camp was moved east to Kades, and from the camp much of the plain of the Huleh and the low country was surveyed. The ruins of the Temple of the Sun were planned and photographed.

On the 24th, the party again marched northwards, and, having pitched camp at Taiyebeh, the triangulation was carried to its most northern point, the great Crusading castle of Beaufort. From a study of the masonry of the four Crusading castles that defended the northern frontier of the kingdom, Beaufort, Toron, Hunin, and Banias, and after comparison with others in different parts of the country, Lieut. Kitchener is led to suppose that they are none of them older than Crusading times, except a portion of Banias, which appears to be slightly older work; and, therefore, that none of them date, as most travellers assert, from Phœnician or even Roman times.

On the 2nd of June, camp was moved to Banias, the Cæsarea Philippi of the New Testament, and the Panium of Josephus. The triangulation was here successfully closed on this side by observing from the Castle. This was the ancient acknowledged source of the Jordan springing out of the cave of Pan in the face of a precipitous rock, and rushing at once in a strong stream through the tangled groves of luxuriant vegetation to the plain below, there to be joined by its rivals in modern writings, the Leddan and the Hasbany. The Hasbany, with less flow of water than either of the other two streams, and joining them after their junction, when they form a mighty stream, cannot be followed as a source of the Jordan. When the other two divide into almost equal streams, the longest course leads to this fountain of Banias, the true source of the Jordan.

In discussing the great depression of the Jordan valley, which is merely a continuation of the great valley extending through Syria, dividing the Lebanon from the Anti-Lebanon, and down which the Leontes and Jordan rivers flow, Lieut.

Kitchener advanced a new theory. There is little doubt that the depression was caused by a fault, and the sliding down of the strata, and that it was once an immense lake; this is proved by the ancient shore lines found at different elevations along its course. The general supposition is, that it has been a continuation of the Gulf of Akaba, and that the gentle rising of 130 miles has cut off the Dead Sea from the ocean. It is curious that on this raised land there is still a well-defined valley, having a fall, and showing the channel of a water-course, as far as known, the whole way. In the north, there is considerable evidence of volcanic action, and a volcano found was exactly in the bed of the valley of the Leontes, at the bend of the river; it has been mentioned previously by Canon Tristram, who noted the way the basalt had flowed down the western side of the Hasbany. These volcanic outbreaks are known to belong to a late period of geological time. Before then, the Leontes, instead of being forcibly turned off at right angles to its course in the most extraordinary bend which makes it cleave through the rocks to the sea, would have flowed into the mighty lake which then covered the plain, and over the southern boundary along the Arraba, which still shows signs of its presence, to the Gulf of Akaba. The only supposition required in this theory is a more abundant supply of water, and of that the country gives striking proof. The extraordinary evidences of the action of glaciers on the rocks, the deep water-courses cut through hundreds of feet of solid limestone, now dry, speak of a former age of rushing torrents. Thus this volcanic outbreak in the Merj Ayun is the key to the present formation of the valley; a very slight cutting through it would again turn the Leontes into its former course down the Jordan valley and into the Dead Sea. The saltness of the Dead Sea may be accounted for by the great natural cliffs of rock-salt found at its southern extremity, and by the many salt springs that are found in that region continually pouring brine into its waters. These cliffs of rock-salt at the Khashm Usdun are a natural crystalline formation, and cannot, therefore, have been deposited by an evaporating sea.

On the 22nd, camp was moved to Nakurah; and from the Râs en Nakurah, the last round of observation, angles were taken, closing the triangulation of the whole of Palestine, and joining very well on the base; the check calculations have proved its accuracy.

On the 11th July, all arrived at Haiffa, after completing the survey of 1000 square miles of country. The whole expenditure was £900, and taking £100 as the cost of the fair drawing, the party may claim to have produced a 1-inch survey at the cost of £1 a square mile.

After four weeks' rest in the Lebanon, the field was taken again on the 23rd August with a reduced party. A long march led to the south country, and 340 square miles in the desert round Beersheba were surveyed. This completed the survey of Palestine; but the early portion required revision, and from 10th October to 22nd November 1700 square miles were revised. The party, having completed all it was sent to perform, then returned to England.

FRIDAY, AUGUST 16, 1878.

The following Papers were read:—

1. *Notes on some Geographical Variations on the Coast of France. By* J. S. PHENÉ, *LL.D., F.S.A.*

Dr. Phené, having for years past taken careful observations and soundings in the Morbihan sea, was of opinion that a very large portion of what was now that inland sea did not exist, in fact nothing that could be so called had existed, in the time of Cæsar. The Ile de Batz, an island near the mouth of the Loire, celebrated for strange and ancient rites, mentioned by classical writers, was now a promontory, and the former littoral line only to be traced with difficulty. Dr. Phené believed that he had discovered the island of Avalon, the reputed place of King Arthur's burial, though from the island having been severed into two by the sea, and the name retained only by the smaller portion, it had been overlooked, and even in the neighbourhood no one knew of it but local fishermen. A dolmen unlike any other in France or Britain on the larger portion, and the traditions of the locality, seemed to put the matter out of doubt.

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2. *On Processes of Map-producing. By* Captain J. WATERHOUSE, *B.S.C., Assistant Surveyor-General of India.*

Before the introduction of lithography, about the beginning of the present century, the only means by which maps could be reproduced was by engraving on metal plates or on wood, both tedious and expensive methods. With the invention of lithography, a new impetus was given to cartography. The new art was, however, scarcely out of its cradle when Joseph Nicéphore Niepce, of Châlons-sur-Saône, experimenting unsuccessfully in endeavouring to find a substitute for lithographic stone, conceived the happy idea of obtaining images on metal plates by the sole agency of light upon thin films of asphaltum or bitumen of Judæa.

Since these first essays of Niepce, the idea of superseding the slow and laborious hand-work of the lithographic draughtsman and engraver by the quicker, cheaper, and more accurate processes of photography has been steadily kept in view.

The first serious attempt to carry out the method practically appears to have been made by Sir Henry James, R.E., in 1855. The result proved the great value of photography for the reproduction of maps, and the enormous saving in time and money that could be effected by its use. In 1860, Captain A. de Courcy Scott, R.E., perfected the process of photozincography, which has since been employed with so much success and advantage at the Ordnance Survey Office, Southampton, and the India Survey Offices in Calcutta, Dehra Dún, Púna, and Madras.

By a curious coincidence, at the very time when this process was being worked out in England, Mr. W. Osborne, of Melbourne, Australia, independently perfected an almost identically similar process of photolithography, which has been extensively used for reproducing the maps of the Australian Colonies.

Little progress was made in the practical working of photolithography or photozincography in India till 1865, when Mr. J. B. N. Hennessey, of the Great Trigonometrical Survey, fairly established the process at Dehra Dún.

The specific advantages to be gained by the use of photography for the reproduction of maps are—

(1.) Rapidity of production and multiplication.

(2.) The perfect fidelity with which the most delicately minute and intricate details are copied.

(3.) The facility with which copies may be obtained on scales larger or smaller than the original.

(4.) The comparative cheapness of the photographic methods.

Notwithstanding these advantages, the use of photography as a means of reproducing maps for publication has not extended so much as might have been expected, in great part owing to the difficulty of making draughtsmen fully understand the requirements to be fulfilled when preparing maps for reproduction, in order to produce satisfactory results, and that they must strictly refrain from using colour, and draw the map neatly in black and white, so that every line may be reproduced of its proper strength, according as the map is to be copied on the same scale as the original, or to be reduced.

Captain Waterhouse described at considerable length the following processes:—The production of the negative; photographic printing on sensitive paper; photolithography and photozincography; photo-Collotype; Woodburytype; photographic engraving; phototypography, and several miscellaneous processes, such as blue prints, bichromate prints, and polographing on copper.

3. *Richthofen, Prejevalsky, and Lake Lob.* *By* E. Delmar Morgan, *F.R.G.S.*

SATURDAY, AUGUST 17, 1878.

This Section did not meet.

MONDAY, AUGUST 19, 1878.

The following Papers were read:—

1. *The Land of Midian. By* Captain R. F. BURTON, *H.B.M. Consul, Trieste.*

The kingdoms of Zibah and Zalmunna have hitherto been vaguely and erroneously laid down. The wandering tribes still apply the term *Arz Madyan* (land of Midian) to the maritime strip, 108 miles long, bounded north by the head of the 'Akabah Gulf, and south by the Wady Surr, the great waterless river-bed upon which the fort El-Muwayláh is built. But Captain Burton also proposes a South Midian beginning at the latter point, extending 105 miles, and ending at the Wady Hamz (N. lat. 25° 55′), where the Egyptian and Ottoman possessions meet. Thus the latitudinal length of the Midianite seaboard is 213 miles, which the windings of the coast prolong to 300. The inner depth is determined by the Shafah line of sub-maritime mountains defining the eastern frontier. Politically speaking, the country all belongs to the Khediv of Egypt, whose predecessors have garrisoned the two forts El-'Akabah and El-Muwayláh since the days of Sultan Selim the Conqueror, in A.D. 1517. Captain Burton assigned to the Jebel El-Tihámah (mountains of the Lowlands), the ghats or fringing ranges of the Arabian Peninsula, an altitude of 6000 to 6500 feet, a figure which the hydrographic chart has exaggerated to 9000.

Captain Burton proceeded to outline the movements of the two expeditions which he commanded in 1877 and 1878, both due to the liberality of the Khediv of Egypt, Ismail I. The four months of travel which ended 1877 and began 1878 were distributed into three excursions:—

1. The northern march, which visited the copper works established by the ancient Egyptians; the ruined capital, "Madiáma," which Ptolemy places in N. lat. 28° 15′; the Fort El-'Akabah, where, also, traces of smelting metal were found; the sulphur-hill, northernmost of the three discovered, and the great gypsum formations of Midian and Sinai. This section concluded with a *periplus* of the perilous 'Akabah Gulf and a narrow escape from shipwreck and the sharks.

2. The central or eastern march to Middle Midian, the course of which was arrested by the villanous Ma'ázeh tribe, then turned southwards, and explored the ruins of Shuwák, the Soaka of Ptolemy (N. lat. 27° 15′). This section concluded with a visit to the turquoise diggings of Zibá; an inspection of the central sulphur-hill, and the ascent of the mighty Shárr mountain which lies behind El-Muwayláh. Geographically speaking, it was the most important, as it brought back details of the Hismá or sandstone plateau bounding the ghats on the East; and of a huge volcanic tract called El-Harrah.

3. The southern march, which began and ended at El-Wijh, covered the region worked for gold by the ancients, and collected details, sketches, and plans of the mines open and closed. A third sulphur-hill was explored; the gold mine El-Marwah of the mediæval Arab geographers was satisfactorily identified, and a classical shrine or temple was found upon the southern bank of the great Wady Hamz.

The expedition, which landed in Arabia on December 19th, 1877, left it on April 18th, 1878. By sea and land, it had covered nearly 2500 miles; of these some 600 were mapped, the crucial stations being determined astronomically. It had measured and planned fourteen settlements, some large enough to be called cities, besides nearly thrice that number of *ateliers*. At least 200 sketches, oil-

colours, water-colours, pencil drawings, and photographs were taken, besides twenty-five tons of rock-specimens. The explorers brought back to Cairo a small ethnological collection of stone implements, rude and worked; coins of ancient Midian, mixed with Roman and Kufic; fragments of copper and bronze, glass and pottery; Nabathæan inscriptions and Arab tribe marks; skulls, spirit specimens of zoology, shells from the shores of the Red Sea, and a *hortus siccus*.

Captain Burton ended his paper by noticing that the terms of the Anglo-Turkish Convention have placed Great Britain, with reference to Arabia, nearly in the same position as that occupied by Rome after the days of Augustus. He found the land wasted and spoiled, far less civilised than it was in the nineteenth century B.C. But he cherishes the conviction that Midian is fated to see better days, and that by the development of her mineral wealth, under the fostering care of European, and especially English companies, this forgotten California, now like Algeria before 1830, will presently rival the rich and fruitful province of Algiers in 1878.

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2. *On a Journey to Fez and Mequinez.* *By* A. LEARED, *M.D.*, *F.R.G.S.*, *M.R.I.A.*

Dr. Leared, who, in May, 1877, accompanied the Portuguese Embassy to the Sultan of Morocco, in addition to many interesting personal and historical details, gives the following particulars of the country on the route followed from Tangier. For some three and a half hours' ride, the land near the city is well cultivated, the first halt being under a range of hills named Kaa-el-Urmil, near the river M'har. After advancing close to the sea and crossing a plain, a river fifty yards wide was forded, and the douar of Garbia reached, two hours from which is a thick grove of wild olive-trees, abounding in nightingales. A succession of hill and plain, but little cultivated, then followed, and Klatta de Raissana was reached, after fording another considerable river. Next day, a great alluvial plain was traversed, through which runs the small river M'Hassen, the distance from which to Alcassar-el-Kebir (historically associated with the destruction of Don Sebastian and his army by the Moors in 1578) is some ten miles of level, little cultivated land, becoming an arid plain at two miles from the town. Dr. Leared estimates the inhabitants as between 5000 and 6000, considering Rohlfs's number of 30,000 as much exaggerated. Beyond Alcassar, two miles of wide and paved footpath were followed, ending at a ford across the Lucos, here about eighty yards broad. Still further on the land was better cultivated, and wheat was being cut (May 25th). The encampment was in the midst of an immense tract, covered with hay going to waste. After passing the bounds of the province of Larache, the river Guarot was crossed by a ford about 50 yards wide, and a rolling prairie traversed, grass and flower-covered, but with no tree or shrub. Ten miles further on, the douar or village of the governor of the Habassie tribe was reached; the next journey being through an immense level tract, with a sea-like horizon to the west. Much of this was cultivated with wheat and barley, with scattered douars and cattle; but the greater part was a fertile waste. The Sebou, one of the chief rivers of Morocco, here 120 yards wide and of considerable depth, was then passed in flat-bottomed boats and by swimming. A flat fertile country followed, with splendid wheat-crops; great tracts of a tall white-flowering wild umbelliferous plant were observed; and a camp was made, close to the village of Bokhara, on the bank of the river Irrdrum, a tributary of the Sebou, on a dead level plain, having to the south a fine amphitheatre-like range of distant hills. Four miles from this, after cresting the commencement of a hilly country, and making a short descent, a halt was made at Zacouta, on flat parched soil, deeply fissured by the summer heat, and abounding with the lesser bustard, a bird not known near the coast. Leaving Zacouta, the road lay through a succession of hills, on the slopes of which was much standing corn; and after a short journey, the party encamped under the mountain of Zarhoun, on the south side of which, less than a mile distant, is the town and sanctuary of Muley Edris-el-Keber. To the right, across a stream with deep banks, and on higher ground, stand the ruins called Cassar Pharaon (Pharaoh's Castle),

12 miles N.E. of Mequinez, and 28 N.W. of Fez, identified by Dr. Leared as the ancient city of Volubilis. After crossing some hills and a large plain, and camp-

Date		Time occupied in travelling	Miles	Temperature in the shade: Early morning	Mid-day	At night	Names of Stopping Places and Remarks
		h m		Fahr.	Fahr.	Fahr.	
May	21	3 30	14			74	Left Tangier; camped at Kaa el Cimil.
	22	3 0	12	69	83	71	Garbia.
	23	5 40	$22\frac{2}{3}$	70	86	72	Klatta de Raissana.
	24	4 0	16	72	91	73	Alcassar.
	25	4 20	$17\frac{1}{3}$	69	90	70	Ben Ouda.
	26	2 35	$10\frac{1}{3}$	71	90	72	Habassie.
	27	2 40	$10\frac{2}{3}$	69	88	73	Beni Hassan.
	28	4 45	19	70	89	74	Bokhara.
	29			72	90	71	
	30			74	93	77	
	31	3 40	$14\frac{2}{3}$	72	91	67	Zacouta. A thunderstorm in the evening, with some rain.
June	1			74	94	80	
	2			74	99	78	
	3			74	88	68	
	4			68	86	72	
	5	2 0	8	69	91	67	Cassar Pharoun.
	6	1 45	7	94	102		Wad Cazar.
	7	1 30	6	76	80	79	Arrived at Mequinez; total time spent in travelling, 39h 25m; distance, $157\frac{2}{3}$ miles.
	8			72	84		
	9			82	87	84	
	10			83	89	86	
	11			83	85	81	
	12			80	81	80	
	13			79	82	79	
	14			78	81	77	Thunderstorm.
	15			78	80	79	Mequinez.
	16			78	81	78	Thunderstorm.
	17			78	82	78	
	18			77	79	77	
	19			77	79	77	
	20			77	78	77	
	21			76	77	75	
	22			75	77	76	
	23	5 40	$22\frac{2}{3}$	74			Left Mequinez; stop beyond Wad Enga.
	24	2 45	11	74		74	Fez; time spent in travelling between Mequinez and Fez, 8h 25m; distance, $33\frac{2}{3}$ miles.
	25			74	98		
	26			72	91	77	Left Fez; camped at Hezana.
	27	6 50	$27\frac{1}{3}$	69		72	Hezana.
	28	8 45	35	70		74	Hadcour.
	29	7 0	28	70		82	Alcassar.
	30	5 10	$20\frac{2}{3}$	72		80	Larache.
July	1	6 55	$27\frac{2}{3}$	74		77	Garbia.
	2	5 35	$22\frac{1}{3}$	75		77	Arrived at Tangier; time spent in travelling from Fez to Tangier, 40h 15m; distance, 161 miles.

ing by the Wad Cazar (river of trees), Mequinez itself was entered. This city is computed to be 157 miles from Tangier, and is more modern-looking than Fez, with wider streets. It is surrounded with high walls, with towers and huge gates, which swarm with hawks, jays, and pigeons, and having an outer circuit of about five miles. The inhabitants are estimated at 25,000, including many Jews, who, though, as usual, insulted and badly treated, contrive to prosper.

After sixteen days' residence in Mequinez and various state ceremonials, the party started for Fez by the northern gate, near which are fine perennial springs. Olive plantations of great extent, and an encampment near a small river, the Wad Jedida, 12 miles from the city, conspicuous for the plenty and beauty of its vegetation, were the only points noticed on the thirty-four miles' ride to Fez, which city seemed to be about two and a half miles long, but narrow. It is surrounded by hills, those on the south side being so close as to overlook the place, and is divided by the river into Old and New Fez, a long street, only seven feet wide, running east and west through the whole of the former division. Its population is estimated at 50,000. There is an extensive palace, Lallah Amina, at two miles' distance, in the midst of a large garden. After a short stay of three days, the party left by a route to the east of that usually followed, commencing with a broad aloe avenue, and passing a small lake, white with salt after evaporation. A succession of hills extended to Woled Jemah, the soil in the latter part being very thin and chalky, but bearing a profusion of flowering caper bushes. Two hours from Woled Jemah is a ford of the Sebou, 150 yards wide; and after fording the wide river Wurga, Hadcour was reached, and afterwards Alcassar. Leaving Alcassar, and crossing the Lucos (a corruption of El Kus), the course lay westward through a country studded with cork oak-trees until arriving at El Araish or Larache, picturesquely situated at the mouth of the Lucos, with its treacherous sand-bar. Larache has a population of about 4000, including one Englishman. After crossing the river in a fourteen-oared galley, the route lay over sand-hills and elevations covered with myrtles and other blooming shrubs, until at length the original road was struck at Resana, and finally Tangier was reached.

On the opposite page is the itinerary, which may be useful to future travellers in this comparatively unknown country.

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3. *On the Progress in the Official Report of the "Challenger" Expedition. By* Sir C. Wyville Thomson, *LL.D., F.R.S., &c.*

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4. *On the Characteristic Features of Alaska, as developed by the U. S. Survey. By* W. H. Dall, *U.S.C.S.*

The territory is divided, topographically, botanically, ethnologically, and in a meteorological sense, into three regions. These regions are not, however, absolutely coincident under the respective heads. The topographical regions are the south-eastern or Sitkan region, remarkable for its rugged and elevated mountains and numerous islands with bold shores; the Aleutian, comprising the Aleutian Islands and the peninsula of Aliaska, also partly mountainous, but of a different character; and lastly, the Yukon region, including the greater part of the area of the territory and composed of the lowlands north of the Alaskan mountains and the Arctic tundri, with, for the most part, shallow water along their coasts. The botanical and meteorological regions are mainly identical with the preceding, but not absolutely so. The Sitkan region is characterised by dense forests of conifers and many plants peculiar to the western slope of the continent; the Aleutian region by an absence of trees, the great development of grasses and herbage, numerous *Ericaceæ*, and a more Arctic physiognomy. The Yukon region is marked by the presence of birch, spruce, willow, and poplar, often forming large forests, of a different character from those of Sitka, and, for the rest, by a chiefly Arctic flora. Meteorologically, the Sitkan (as well as the British Columbian coast) is marked

by great precipitation and mild and equable temperature; the Aleutian region, by the prevalence of fog, a somewhat colder climate and a diminished rainfall and the Yukon region by a truly Arctic climate with a small precipitation.

The ethnological divisions comprise those areas inhabited by tribes of Innuit stock, by the Tinneh or Athabascan tribes, and by the T'linkits or Kaloshians. The latter inhabit the Sitkan region; the Eskimo or Innuit the shores of the Yukon and Aleutian regions eastward to Mount St. Elias; and the Tinneh tribes the interior, reaching the sea coast only at Cook's Inlet. The native population is believed to number between 20,000 and 25,000, and the present white population is very small.

The commercial products of the different regions are also characteristic. The Sitkan region, beside a small trade in continental furs, offers salmon, timber, and minerals, the value of which has not yet been fully tested. The Aleutian region is at present of most commercial importance, affording the sea-otter, fur-seal, and cod-fish. From the Yukon region, come the ordinary continental furs, while the adjacent seas support the whale and walrus fisheries.

The Sitkan and Aleutian regions reproduce very nearly the conditions of the coast of Norway, while the Yukon region may be compared to the Archangel district of Russia.

The tribes of Innuit stock (including the Aleuts) are generally of a peaceable and tractable nature: those of Tinneh stock more independent, but still easily controlled: while the T'linkits are, of all American natives, the most intractable and difficult to deal with.

The T'linkits, while rejecting all attempts to subdue or improve them, have a well-advanced semi-civilisation of their own, particularly shown in their carvings, advanced totemic system, mythology, and permanent dwellings. The Innuit, though of shorter average stature than the whites, are a very different race physically from their stunted cousins of Greenland, and are intelligent, athletic, and ingenious. The Aleuts have already adopted many features of civilisation from the Russians.

The Tinneh are nearly all in a condition similar to those of the Hudson Bay Territory, but are much more amenable to improvement than the T'linkits. Already several missions have been established, with a tolerable prospect of success.

The results obtained by the explorations of the Coast Survey are in process of preparation for publication in detail, and will eventually be printed and issued under the direction of the Superintendent of the Survey by the United States Government.

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5. *On the Acquisition by England of Cyprus, and some Observations on the Islands in the Levant.* By J. S. PHENÉ, *LL.D., F.S.A.*

Dr. Phené described the physical features of the islands of Chios, Mytilene, Lemnos, Imbros, Thasos, and Samothrace; the relation of the Cyclades to the great range of Pindus in lateral offsets, of which the Cyclades appeared to be the summits of former ranges, now (except as to these summits) submerged. Reference was made to the great aqueous stratification in Asia Minor and Southern Thrace, which, being undisturbed, could not (geologically speaking) be remote; and to a remarkable tradition given by Diodorus Siculus, that the Euxine had at a far distant period burst its bounds, and rushed westward to the Mediterranean Sea, that in this convulsion some of the islands had become submerged, and that the champaign country of the island of Samothrace was permanently so, and that even indications of cities by the recovery of parts of buildings from the sea were sometimes found. It was possible that this convulsion represented the sinking down of the mountain ridges, of which the summits were now represented by the various islands stretching south from the several headlands of the Peloponnesus. Dr. Phené ascended Samothrace, and was, so far as he could learn on the island, the only person not being a native who had made the ascent, which was very difficult. The height was slightly over 5200 feet, but it was the whole climb of this from the sea

level. The climates, culture, and salubrity of the different islands were dwelt on; Mytilene, from its rich gardens, good roads, and delightful air, being, with its splendid and secluded harbours—the entrance to the larger one only requiring a little blasting to make it easy of ingress—considered more adapted for British occupation than Cyprus. Chios had also its advantages. Cyprus had a variety of climate, so that the debility produced by the heats in the south could be relieved by a retreat to the northern coast, which is cooled by the breezes coming from the Karamanian mountains. It was our first acquisition towards the tactics of the ancient commercial nations, both the Phœnicians and the Venetians having occupied Cyprus and other Levantine islands.

TUESDAY, AUGUST 20, 1878.

The following Papers were read :—

1. *On the Best Route to attain a high Northern Latitude, or the Pole itself. By* JOHN RAE, *M.D., LL.D., F.R.G.S.*

2. *Geographical Significance of North Polar Ice. By* E. L. MOSS, *M.D.*

3. *Livingstonia.—The Opening up of the East African Lake District. By* JAMES STEVENSON, *F.R.G.S.*

This paper is in continuation of that read in Section F at the Glasgow Meeting of the British Association.

The intention in founding settlements in South-Eastern Africa was the promotion of the Christian civilization of the natives, especially by the system of Industrial Missions, tried with success in Southern Africa.

The new mission settlement was placed in the Nyassa region, which is accessible by the only considerable rivers of Eastern Africa. The immediate results of its establishment were eminently discouraging, for a hostile tariff was issued, and the exclusive right of steam navigation on the rivers Zambesi and Shiré was offered to a Portuguese subject, the concession being for thirty years.

This exclusiveness has gradually passed away. The slave-trade terminated by treaty in 1877, and the Portuguese Legislature passed a tariff by which they limited themselves to transit duties of 3 per cent. to countries situated beyond the confluence of the rivers Zambesi and Shiré, and to other countries outside their provinces.

A steam launch was got ready, and application made to use her for the purposes of the settlement, which has resulted in the opening of the navigation of both rivers. The launch, which will carry from 10 to 20 tons, is now on her way to Quillimane.

The Shiré Junction road past the cataracts of the Shiré is also under construction by Mr. Stewart, C.E., of which a section exhibited showed no gradients exceeding 1 in 20. The steamer *Ilala* takes the traffic on to Livingstonia and the north end of Lake Nyassa.

To work this trade, the "Livingstonia Central Africa Company, Limited," has recently been formed in Glasgow.

The tribes of Nyassa are of the Kaffir family of races, their languages being of similar construction, although the tribes vary considerably from each other.

In the Lower Shiré, an industrious but unwarlike people, the Manganja, have as their chiefs some of Livingstone's Makololo followers, who are opposed to slavery.

The Upper Shiré and the southern part of Lake Nyassa are surrounded by chiefs of the Ajawa race, who are still under Arab influence, but the slave trade is gradually dying out since its prohibition on the coast.

Towards the middle and north end of the lake, on the west side, the pressure of a race called the Maviti or Mazitu is greatly felt by the inhabitants, who are being gradually absorbed. These Maviti are Zulus who crossed the Zambesi forty years ago. They retain the bull-hide shield and spear, and dress their hair in the

Kaffir ring, but are much mixed, and though retaining the tactics, have hardly the courage of the Zulu race. Towards the north end, they have met with more warlike races and have more of the characteristics of the Zulu. Their great chief or Chipatula resides on the highest lands west of Nyassa, about the 11th degree of latitude.

The dominant power north of the lake is the kingdom of Usanga or Urori, of which the chiefs are said to have come from Madagascar. The present chief is Meréré, whose town is on the slope northwards of the Kondi mountains. Between them and the lake are the Wachunga, belonging to Meréré, without clothing, but with some aptitude for industry.

East of the lake, behind the Livingstone mountains, are said to be the Gwangwaras, a very warlike people who work in iron.

The people of the neighbourhood have lately grown provisions, sugar-cane, &c., much more largely, finding a market at the settlement, and this if extended to various articles by the action of the new Company will probably cause the chiefs no longer to sell their people.

The Livingstonia staff have also assisted in forming a settlement on the Shiré junction road, which will be of use to the people under the Makololo Chief. There is here a mission station with a school. The rearing of cattle has been successful here, and also of European grain and vegetables, the site being 3500 feet above the level of the sea.

The next station is proposed to be near the centre of the west side of the lake, with the hope of influencing the Maviti, of whom the older persons still speak Zulu. While retaining Livingstonia as an important station, with a good harbour suitable for commerce, experience shows that a higher portion should be sought. So far, relations with the Maviti have been opened very favourably.

Last year, a second circumnavigation of the lake was made by Dr. Stewart, of Lovedale, and Dr. Laws, of Livingstonia. At the north end they commenced intercourse with the natives at the Kambwe, about fifty miles, and at the Rombashi, about fifteeen miles from the north-east termination of the lake.

From the first they found that there was a rather mountainous approach to Lake Tanganyika, and from the second one more level, but, finding the natives excited by their sudden appearance, they only paved the way for future exploration. Near the upper end of the Livingstone Mountains they saw what appeared to be a gorge, extending towards S.E. by E. true, which they were informed was the pass used in visiting the Gwangwaras. They intended to have visited Meréré, whose capital lies five days to the north of the Rombashi, but were prevented by the attitude of the Wachungu, who, though cordial at first, threatened a coalition of the neighbouring chiefs against them, the steamer eventually sailing to the Kambwe to avoid a collision.

The maps prepared in anticipation of exploration by the Mission parties were found useful, the position of the mountain ranges, rivers, towns, and highways having been estimated with sufficient accuracy to be a substantial guide. Native information indicates that the distance between Lakes Tanganyika and Nyassa, which was a disputed point, is about 200 miles, which would require the acceptance of Mr. Stanley's position of the south end of Tanganyika, which differs from Livingstone's, or of a more easterly position of the north end of Lake Nyassa, according to an observation taken on the Kondi Mountains, by the late Captain Elton's party.

The Eucalyptus has been introduced with success on the low ground at Livingstonia, and by the kindness of the Governor-General in Council at Madras, Wardian cases, containing cinchona, tea, and coffee plants, have been sent there and to Blantyre.

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4. *Cyprus.* *By* Major Wilson, *R.E.*, *F.R.S.*

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5. *On the Geographical Distribution of the Tea Plant.* *By* A. Burrell, *F.S.S.*

Tea, as a beverage, was known in Europe in the beginning of the sixteenth century, became a regular article of consumption in the seventeenth, formed one of the largest imports from China in the eighteenth, and is now the special beverage of all English-speaking peoples, both in the New World and the Old. The botany, method of culture, and modes of manipulation were, however, little known here till about forty years ago. The Jesuit missionaries in China and Japan were our first informants of the virtues of tea. The Portuguese and the Dutch, who, long before our East India Company was established, traded with these countries, introduced it commercially to Europe, and there is evidence of its use in England in 1610, during the reign of James I. It was in common use during the Commonwealth, and the first Act of Parliament after the Restoration was passed to levy a heavy duty on it.

The tea plant first reached Europe in 1763, when Linnæus received a seedling. The earliest plant that flowered and produced seed was at Zion House, near London, in 1768. In China, the plant was in common use from the seventh century; in Japan, from the eighth. It grows in these countries up to 42° north latitude, and is capable of being grown as far of south latidude, though the best tea is produced in China between 27° and 30° north latitude. Up to the first quarter of the present century, all the tea-consumption of the world was supplied from China, with a very little from Japan. In 1827, the culture was introduced by the Dutch in Java, and has ever since proved a successful undertaking. In 1834, immediately after the abolition of the East India Company's monopoly of trade to the East, tea was introduced from China into India, then first becoming a profitable business. Next year, the plant was discovered growing wild in Assam. Tea, both from the China plant and from this Assam kind, is now grown throughout all India, and with the result that our great dependency is producing tea which China, in her more palmy days, and less so than ever now, could not rival. India, beginning with a production of only four pounds in 1840, now sends into this country forty millions of pounds—as great a quantity as was consumed in the whole of the United Kingdom in 1837. In Asia, the tea plant is distributed in the Corea, Tonquin, Cochin China, Annam, Ava, and Burma, where it is cultivated to some extent, but only for native consumption. It was introduced to Brazil in 1827. The French attempted its cultivation in 1841. It is now growing in Mauritius, the Isle of France, St. Helena, at Singapore, in Ceylon, and our Australian Colonies. In the West India Islands it has also been recently introduced, and a good account of its condition in Jamaica has been given. Nor have our American cousins neglected it. They sent to China in 1857 for plants, and tried the culture near Washington, in Virginia, and Carolina; quite recently they have tried it in California, and near Baltimore. As to the original home of the tea plant, in Japan it was admitted on all hands not to be indigenous. In China, it was long held to be native to the soil, but more recent researches have thrown doubt on this point, and the balance of evidence seems to point to the Assam Valley of India, along the course of the Brahmapootra, as its original seat. This is supported by the fact that, while in China the tea plant is never found thoroughly wild away from man's habitation, and is more of a bush than a tree, in Assam, on the other hand, and in the hill ranges surrounding that valley, it is found everywhere growing wild, and attaining great height, usually fifteen to twenty feet (and even by a report just received from India, sixty to eighty feet), and of the girth of three to four feet, among the secluded Naga hills. A long list of authorities, from Marco Polo and his learned editor, Colonel Yule, the Jesuit Missionaries, and more recent travellers, down to the recent works of Richthofen, Margary, Baber, and Gill, all afford evidence of the tea growing wild throughout the vast stretch of country intervening between the frontiers of India and China, and on either side, and

constantly of smaller dimensions as it approached China, thus supplying ground for the contention, which is further supported by the legends of China and Japan, that the tea plant was introduced there by a Buddhist missionary from India.

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6. *Influence of the Straits of Dover on the Tides of the British Channel and North Sea. By* Sir WILLIAM THOMSON, *F.R.S.*

The conclusions are—

1. The rise and fall of the water surface, and the tidal streams throughout the North Sea, north of the parallel of 53° (through Cromer in Norfolk and the North Coast of Holland and Hanover) are not sensibly different from what they would be if the passage through the Straits of Dover were stopped by a barrier.

2. The main features of the tides (rise and fall and tidal streams) throughout the British Channel, west of Beachy Head and St. Valéry-en-Caux, do not differ much from what they would be if the passage through the Straits were stopped by a barrier between Dover and Cape Grisnez (Calais).

3. A partial effect of the actual current through the Straits is to make the tides throughout the Channel, west of a line from Hastings to the mouth of the Somme, more nearly agree with what they would be were there a barrier along this line, than what they would be if there were a barrier between Dover and Cape Grisnez.

4. The chief obviously noticeable effect of the openness of the Straits of Dover on tides west of Beachy Head is that the rise and fall on the coast between Christchurch and Portland is not much smaller than it is.

5. The fact that the tidal currents to the westward commence generally an hour or two before Dover high water, and to the eastward an hour or two before Dover low water, instead of exactly at the times of Dover high and low water, is also partially due to the openness of the Straits of Dover.

6. The facts referred to in Nos. 4 and 5 are wholly due to two causes—(1) The openness of the Straits of Dover; (2) fluid friction (in eddies along the bottom and in tide races). It is certain that (1) and it is probable that (2) is very sensibly influential. Without farther investigation it would be vain to attempt to estimate the proportionate contributions of the two causes to the whole effect.

7. It is certain that were the Straits of Dover barred, and were the water frictionless, there would be a *nodal line* (or line of no rise and fall) across the Channel from somewhere near St. Alban's Head on the English coast to somewhere near Cape La Hogue or Cherbourg or Cape Barfleur on the French coast; that west of this line the time of low water, and east of this line the time of high water, would be exactly the same as the time of high water at Dover; and that throughout the Channel the water would be flowing eastwards while the tide is rising at Dover, and westwards while the tide is falling at Dover.

8. Understanding from Fourier's 'Elementary Principles of Harmonic Analysis' that all deviations from regular simple harmonic rise and fall of the tide within twelve hours are to be represented by the superposition of simple harmonic oscillations in six-hour period, four-hour period, three-hour period, and so on, like the "overtones" which give the peculiar characters to different musical sounds of the same pitch, the six-hourly oscillation which gives the double low water at Portland and the protracted duration of the high water at Havre,* is probably due to the complex harmonic character of the current through the Straits of Dover—that is to say, definitely, to a six-hour periodic term in the Fourier series representing the

* From Admiralty Tide Tables for 1878, page 159:—"At Havre, on the French coast, the high water remains stationary for one hour, with a rise and fall of three or four inches, ... and only rises and falls thirteen inches for the space of three hours; this long period of nearly slack water is very valuable to the traffic of the port, and allows from fifteen to sixteen vessels to enter or leave the docks on the same tide."

quantity of water passing through the Straits per unit of time at any instant of the twelve hours. The double high-water experienced at Southampton and in the Solent and at Christchurch and Poole, and still further west, which is generally attributed to the doubleness of the influence experienced from the tidal streams on the two sides of the Isle of Wight, seems to have a continuity of cause with the double low water at Portland, which is certainly allied to the protracted high water of Havre, a phenomenon quite beyond reach of the Solent's influence. It is probable, therefore, that the double high water in the Solent and at Christchurch and Poole is influenced sensibly by the current through the Straits of Dover; even though the common explanation, attributing them to the Isle of Wight, be in the main correct.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

President of the Section—Professor J. K. Ingram, LL.D., F.T.C.D., M.R.I.A

THURSDAY, AUGUST 15, 1878.

Professor Ingram gave the following Address:—

Had I been called upon at any other time to preside over this Section, I should have followed the example of most of my predecessors, in selecting as the subject of the discourse which it is usual to deliver from this chair, some one of the special economic questions of the day, which my knowledge might have enabled me most adequately, or, let me rather say, least inadequately to treat. But I have felt that the matter with which I should deal has been practically determined for me beforehand. An important crisis in the history of our Section has taken place. Its claim to form a part of the British Association has been disputed. Some of the cultivators of the older branches of research but half recognize the right of Political Economy and Statistics to citizenship in the commonwealth of science; and it is not obscurely intimated on their part that these studies would do well to relinquish pretensions which cannot be sustained, and proceed, with or without shame, to take the lower room to which alone they are entitled.

How far this sentiment is entertained by those who would be recognized as the best representatives of the mathematical, physico-chemical and biological sciences, I am unable to say. But it is natural to suppose that no one clothed with an official character in the Association could have assumed towards us such an attitude as I have described, unless supported by a considerable weight of opinion amongst those within the body who are regarded as competent judges. Still more—and this is what lends a peculiar gravity to the incident—such a step could scarcely have been taken if the general mass of the intelligent public entertained strong convictions as to the genuinely scientific character of political economy, as it is usually professed and understood amongst us. It is, in fact, well known that there is a good deal of scepticism current on this question. There may be seen in various quarters evidences sometimes of contemptuous rejection of its claims, sometimes of uneasy distrust as to their validity. And even amongst those who admit its services in the past, there is a disposition to regard it as essentially effete, and as having no scientific or practical future before it.

When some of our leading economists met not long ago to celebrate the centenary of the publication of the 'Wealth of Nations,' it was plain from the tone of most of the speakers that the present position of their studies, as regards their general acceptation and public influence, was considered to be far from satisfactory.

"To those who are interested in economic science," says a recent writer in 'Mind,' "few things are more noticeable than the small hold which it has upon the thoughts of our generation. Legislation has been directly influenced by it in the past, and the results of the application of its doctrines are manifest in every department of our laws; yet in spite of its triumph in this region, we find a widespread tendency to look on its teaching with suspicion."

"I seem to observe," said Professor Cairnes in 1870, "in the literature and

social discussions of the day. signs of belief that political economy has ceased to be a fruitful speculation; nay, I fear I must go further and admit that it is regarded by some energetic minds in this country as even worse than unfruitful—as obstructive—a positive hindrance in the path of useful reform. . . . It is not denied that the science has done some good; only it is thought that its task is pretty well fulfilled."

The attitude which the working classes generally take up with respect to political economy, may be seen from Mr. Howell's candid and instructive book on the Conflicts of Capital and Labour.

Professor Jevons has recognized quite recently the state of facts indicated by these testimonies, though he has no misgiving as to any grounds for it in the current methods or doctrines of political economy; if the public do not like the science, so much the worse, he thinks, for the public—"the fact is," he says, "that just as physical science was formerly hated, so now there is a kind of ignorant dislike and impatience of political economy."

It is plain, therefore, that the low estimate of the studies of our Section which is entertained by some members of the Association, is no isolated phenomenon, but is related to a mass of opinion outside the body—that, in fact, the crisis which, as I have said, has shown itself in the Association with respect to our Section, is only the counterpart, in a more limited sphere, of a crisis in the history of economic science, which is apparent on the face of English—and, as I shall point out by and by, not of English only, but of European—thought. It is important to understand the origin and significance of this state of things; and to that subject, accordingly, I purpose to direct your attention.

We must take care to distinguish, at the outset, between two views which are sometimes confounded—namely, between the opinion that economic facts do not admit of scientific investigation, and the quite different opinion that the hitherto prevailing mode of studying those facts is unsatisfactory, and many of the current generalizations respecting them unsound. That economic phenomena are capable of scientific treatment is a proposition which I do not intend to spend time in demonstrating. It is comprehended in the more general question of the possibility of a scientific Sociology; and any one who disputes it will have enough to do in combating the arguments by which Comte, and Mill, and Herbert Spencer have established that possibility. Nor do I intend to waste words in showing that, if there be a science of society, no other branch of investigation can compete with it in importance or in dignity. It has the most momentous influence of all on human welfare. It receives contributions from all other departments of research—whether in the ascertainment of results to be used for its purposes, or in the elaboration of methods to be applied in its inquiries. It presides, in fact, over the whole intellectual system—an office which some, mistaking the foundation for the crown of the edifice, have claimed for Mathematics. It is the most difficult of all the sciences, because it is that in which the phenomena dealt with are most complex and dependent on the greatest variety of conditions, and in which, accordingly, appearances are most deceitful, and error takes the most plausible forms. That the professors of the more stably—because earlier—constituted branches of knowledge should ignore the claims of this great department of inquiry would be doubly disastrous—first, by leaving the scientific system without its necessary completion in a true theory of the highest and most important class of phenomena accessible to our researches; and secondly, by tending, so far as prejudice and misconception can temporarily produce such an effect, to hand over to minds of insufficient power, and destitute of the necessary preparation, studies which, more than any others, require a strong intelligence, disciplined in the methods and furnished with the results of the sciences of inorganic and organic nature. There is, in my judgment, no duty more incumbent in our day on the professors of these last, than that of recognizing the claims of Sociology, whilst at the some time enforcing on its cultivators the necessity of conforming to the genuine scientific type. Yet it is now sought to expel from this Association, which ought to represent the harmonious union of all positive research, the very limited and inadequate portion of the science of society which has ever found recognition in its scheme.

I assume, then, that economic phenomena are proper subjects for scientific

treatment. This I imagine the public at large are not disposed to doubt, though they may not repose much confidence in the methods actually followed. But, strangely enough, a professor of political economy has recently disputed the possibility, or at least the utility, of a scientific handling of economic questions. Professor Bonamy Price, of the University of Oxford, who has published a volume in which several of those questions are handled with much ability and freshness of treatment, not only repudiates a scientific character for his own inquiries, but alleges the scientific method to be a mistake. According to him, ordinary people are right in believing that they can arrive at truth on these questions by the aid of their natural lights, by their untrained sagacity,—that they can take a shorter and far clearer path through their own observations, than through what he calls "the tangled jungle of scientific refinements." In plain terms, he is in favour of relegating the study of economic phenomena to the domain of empiricism—to what is called the common sense of practical men.

A more fatal suggestion could not, in my judgment, be made. I shall have to express the opinion, that the prevalent methods of economic research and exposition are open to grave criticism; but how can this be remedied by throwing ourselves on the undisciplined and random inspirations of so-called common sense? It was "common sense" that long upheld the mercantile system; and indeed there is scarcely any error that it has not, at different times, accepted and propagated. What security can there be in this as in other branches of inquiry against endless aberrations and confusions, but systematic observation and analysis of the phenomena, resulting in a body of ascertained and reasoned truth; and what is this but science? I am forced to say that Professor Price seems to me to labour under radical misconception as to the nature and conditions of science. Because the facts of the production and distribution of wealth have always gone on spontaneously amongst mankind, and definite modes of social action with respect to them have progressively established themselves, economic investigation, he argues, adding nothing to what men have with more or less sagacity and intelligence always practised, cannot be regarded as having the nature of a science. But it might be similarly shown that there is no science of human nature, for the intellectual processes, the feelings, and the practical tendencies of man have always been similar; they have not waited for science to develop themselves and pass into action; rather their long continued spontaneous action was the necessary condition of the science that studies them. So, too, with respect to all human action on external nature—practice always must precede theory; art, more or less intelligent, must precede science. Science is simply the ascertainment and co-ordination of laws; a law is the statement of a general fact; we explain a particular fact by showing that it is a case of a more general fact. Now, from the beginning to the end of his own book, Professor Price is endeavouring to ascertain such general facts, and to explain particular facts by means of them—in other words, he is busied upon science without knowing it. He rests much of the importance of economic studies, which he regards as essentially practical, on their efficacy for uprooting the evil weed of false theory; but theory of some sort will always be necessary. *On ne détruit que ce qu'on remplace;* and the only way of extinguishing false theory is to establish the true.

I therefore repudiate the doctrine of Professor Price, and I hold by the truth, which has indeed now become a philosophic commonplace, that social phenomena generally, and amongst them the economic phenomena of society, do admit of scientific treatment. But I believe, though on different grounds from his, that the mode in which the study of these phenomena has been conceived and prosecuted in the hitherto reigning school, is open to serious objections; and the decline in the credit and influence of political economy, of which I have spoken, appears to me to be in a large measure due to the vicious methods followed by its teachers. The distrust of its doctrines manifested by the working classes is no doubt in a great degree owing to the not altogether unfounded belief, that it has tended to justify too absolutely existing social arrangements, and that its study is often recommended with the real, though disguised, object of repressing popular aspirations after a better order of things. And it is doubtless true that some of the opposition which political economy encounters, is founded on the hostility of selfish interests, marshalled

against the principles of free-trade, of which it is regarded as the representative. But it is not with manifestations of this kind, which belong to politics rather than philosophy, that I am now chiefly concerned. It is more appropriate to this place to point to the growing coldness or distrust exhibited by the higher intellects towards political economy—a fact which lies on the surface of things, and shows itself everywhere in contemporary literature. The egoistic spirit in which it is steeped may explain the continued protest which Carlyle and Ruskin have, mainly as moral preachers, maintained against it—though that very spirit is, as I shall show, closely connected with vicious method. But what are we to say of Miss Martineau's final judgment? Speaking in her 'Autobiography' of that part of her career in which, as Professor Jevons says, "she successfully popularized the truths of political economy in her admirable tales," she tells us that what she then took to be the science of political economy as elaborated by the economists of our time, she had come to regard as being no science at all, strictly speaking.—"So many of its parts," she adds, "must undergo essential change, that it may be a question whether future generations will owe much more to it than the benefit (incalculable to be sure) of establishing the grand truth, that social affairs proceed according to great general laws, no less than natural phenomena of every kind." Here is a conclusion resting essentially on intellectual, not moral, grounds; and I presume Professor Jevons will not explain it as a result of ignorant impatience.

But it is no longer necessary to consider scattered indications of the feeling of eminent individualities on this matter, for of late years the growing dissatisfaction has risen to the dimensions of a European revolt, whose organs have appeared not in the ranks of general literature, but within the sphere of economic investigation itself. It is a characteristic result of the narrowness and spirit of routine which have too much prevailed in the dominant English school of economists, that they are either unacquainted with, or have chosen to ignore, this remarkable movement.

The largest and most combined manifestation of the revolt has been in Germany, all whose ablest economic writers are in opposition to the methods and doctrines of the school of Ricardo. Roscher, Knies, Hildebrand, Nasse, Brentano, Held, Schmoller, Schaffle, Schönberg, Samter, and others, have taken up this attitude. In Italy a group of distinguished writers, amongst whom are named Luzzatti, Forti, and Lampertico, follow the same direction, and have a special organ in which they advocate their views. In Denmark a similar scientific evolution is in progress, chiefly under the leading of Frederiksen. The eminent Belgian publicist, M. de Laveleye, has done much to call attention to these new tendencies of economic doctrine, in which he himself participates. In England a corresponding movement, by no means imitative, but on the contrary, highly original in character, is represented by Mr. Cliffe Leslie, whom I mention with pride as an alumnus of this University. In France, the new direction is not so marked in the economic world, strictly so called, though in that country it really first appeared. For the vices of the old school, which have led to the development of the new, were powerfully stated more than forty years ago by a French thinker, who is too little studied by the mass of his countrymen, Auguste Comte, the greatest master who has ever treated of sociological method. How far the Germans may have been led by national prejudice to ignore his influence in the formation of their views, I will not undertake to say; but there is no doubt of the fact that the tendencies they have sought to impress on economic studies are largely in accordance with the teaching on that subject contained in his 'Philosophie Positive.'

In the admirable chapters of that work, in which he described the normal conditions and method of social science, whilst paying a warm tribute to the merits of Adam Smith, he criticized what he considered the aberrations of later political economists. The late Professor Cairnes, of whom, as a member of this University, we are justly proud, and whom, even when I differ from him, I name with all the respect due to an able and earnest searcher after truth, attempted an answer to some of these strictures of Comte, which again elicited a reply from Mr. Frederic Harrison. Considering the criticisms of the great Frenchman to have been perfectly just when he wrote them, and only requiring a certain correction now in view of the healthier tendencies apparent in several quarters since his work was

published, I shall dwell at some length on the several grounds of his censures, stating and illustrating them in my own way, which will differ considerably from the mode of treatment which they received in the controversy to which I have referred. Those grounds, though nowhere by him formally enumerated, are essentially reducible to four, having relation—first, to the attempt to isolate the study of the facts of wealth from that of the other social phenomena; secondly, to the metaphysical or viciously abstract character of many of the conceptions of the economists; thirdly, to the abusive preponderance of deduction in their processes of research; and fourthly, to the too absolute way in which their conclusions are conceived and enunciated. It will be found that these heads cannot be kept strictly apart, but run into each other at several points. The separation of them will, however, serve to give distinctness and order to the discussion.

I. The first objection is, as I have stated, to the pretension of the economists to isolate the special phenomena they study, the economic phenomena of society, from all the rest—its material aspect from its intellectual, moral, and political aspects, and to constitute an independent science, dealing with the former alone, to the exclusion of the latter. This question as to the relation of economic studies to the general body of human knowledge, is really the most radical and vital that can be raised respecting them, and on it more than on any other depends, in my opinion, the future of these studies.

It is sometimes sought to get rid of this question in a very summary manner, and to represent those who raise it either as weakly sentimental persons, who shrink from studying the conditions of wealth apart, because there are better and higher things than wealth; or as persons of confused intellect, who wish to mix together things which are essentially different in their nature. On the former of these imputations it is unnecessary to dwell. I am far from undervaluing sentiment in its proper sphere; but I take up no sentimental ground on the present question. In denying the propriety of isolating economic investigation, I appeal to considerations derived from the philosophy of science. The second allegation is, therefore, the only one with which I am now concerned.

In a recent elementary treatise on political economy, by a well-known writer, it is argued:—"We must do one thing at a time; we cannot learn the social sciences all at the same time. No one objects to astronomy that it treats only of the stars, or to mathematics that it treats only of numbers and quantities. . . There must be many physical sciences, and there must be also many social sciences, and each of these sciences must treat of its own proper subject, and not of things in general."

But a little consideration will show that these remarks touch only the outside of the question. Of course we must do only one thing at a time. Only one out of several branches of a subject can be considered at a time; but they are yet branches of a single subject, and the relations of the branches may be precisely the most important thing to be kept in view respecting them. It might be said: "It is important, no doubt, that plant life and animal life should both be understood; but zoology and botany are different sciences; let them be studied apart; let a separate class of *savants* be appropriated to each, and every essential end is secured." But what says Professor Huxley, in unison with all the most competent opinion on the subject?—"The study of living bodies is really one discipline, which is divided into zoology and botany simply as a matter of convenience." They are, in fact, branches from the common stem of Biology, and neither can be rightly conceived without bearing this in mind. Now I maintain that for still stronger reasons the several branches of social science must be kept in the closest relation.

Another biological analogy will place these reasons in the clearest light. When we pass from the study of the inorganic world to that of the organic, which presupposes and succeeds to the former, we come upon the new idea of a living whole, with definite structures appropriated to special actions, but all influencing one another, and co-operating to one result—the healthy life of the organism. Here, then, it is plain that we cannot isolate the study of one organ from that of the rest, or of the whole. We cannot break up the study of the human body into a number of different sciences, dealing respectively with the different organs and functions,

and, instead of a human anatomy and physiology, construct a cardiology, a hepatology, an enterology. It is not of course meant that special studies of particular organs and functions may not be undertaken—that they may not be temporarily and provisionally separated from each other in our researches; but the fact insisted on is, that it is essential to keep in view their relations and interactions, and that therefore they must be treated as forming part of the subject-matter of one and the same science. And what is thus true of theory is also true of practice—the physician who had studied only one organ and its function would be very untrustworthy even in the therapeutics of that organ. He who treats every disease as purely local, without regard to the general constitution, is a quack; and he who ignores the mutual action of the *physique* and the *moral* in disease, is not properly a physician, but a veterinary.

These considerations are just as applicable, *mutatis mutandis*, to the study of society, which is in so many respects kindred to biology. The most characteristic fact about what is well called the social system, is the consensus of its different functions: and the treatment of these functions as independent is sure to land us in theoretic and practical error. There is one great science of Sociology; its several chapters study the several faces of social existence. One of these faces is that of the material well-being of society, its industrial constitution and development. The study of these phenomena is one chapter of Sociology, a chapter which must be kept in close relation with the rest.

The justice of this view is clearly seen when we consider the two-fold aspect of Sociology as statical and dynamical—that is, as dealing on the one hand with laws of coexistence, and on the other with laws of succession. As in biology we have, alongside of the theory of the constitution and actions of an organism, the further theory of its development in time; so in Sociology we have, beside the doctrine of the constitution and actions of society, the doctrine of its evolution from a primitive to a higher condition. Now nothing is plainer than that in the course of the human evolution the several social elements did not follow separate and independent processes of growth. The present economic state, for example, of the nations of western Europe, as a group, or of any individual one amongst them, is the result of a great variety of conditions, many of them not in their own nature economical at all. Scientific, moral, religious, political ideas and institutions have all concurred in determining it. But if they worked in this manner in the past, it follows that they are working so in the present. It is therefore impossible rationally to conceive or explain the industrial economy of society without taking into account the other coexisting social factors.

In nothing is the eminent superiority of Adam Smith more clearly seen than in his tendency to comprehend and combine in his investigations all the different aspects of social phenomena. Before the term "social science" had been spoken or written, it could not be expected that he should have conceived adequately the nature and conditions of that branch of inquiry, much less founded it on definitive bases—a task which was to be achieved more than fifty years later by the genius of Comte. But he proceeded as far in this direction as it was possible to do under the intellectual conditions of his time. In his 'Theory of Moral Sentiments' he promises to give in another discourse "an account of the general principles of law and government, and of the different revolutions they have undergone in the different ages and periods of society, not only in what concerns justice, but in what concerns police, revenue, and arms, and whatever else is the subject of law." Here is no separation of politics, jurisprudence, and political economy, but rather an anticipation, wonderful for his period, of general sociology, both statical and dynamical—an anticipation which becomes more extraordinary still, when we learn from his literary executors that he had formed the plan of a connected history of the liberal sciences and elegant arts, which would have supplied, in addition to the social aspects already mentioned, a view of the intellectual progress of society. Of this last undertaking there remains to us only the remarkable essay on the history of astronomy, which is evidence at once of his thorough acquaintance with that branch of science, and of his profound philosophical conceptions on the nature of scientific inquiry in general. The other project too was never fully

carried out; it may well be thought because it was essentially premature. The 'Wealth of Nations' is in fact a part of that larger design; and though in this work he has for his main subject the economic phenomena of society, he has incorporated into it so much that relates to the other social aspects that he has on this very ground been censured by some of the later economists. Mill, however, who of all his English successors was the most large-minded and the best equipped in respect of general culture, has recognised it as the great characteristic excellence of Smith that "in his applications of political economy, he perpetually appeals to other and often far larger considerations than pure political economy affords." In consequence of this admirable breadth of view, the study of the work of Adam Smith is, I believe, more fitted than that of the writings of any other economist, to cultivate in theorists a philosophic, and in practical men a statesman-like, habit of mind.

In striking contrast with this spirit of the master is the affectation, habitual in his followers, of ignoring all considerations except the strictly economic, though in doing so they often pass over agencies which have important effects on material well-being. Thus, when Senior is led to make some observations of the utmost importance and interest, on the very doubtful advantage to a labouring family of the employment of the mother and the children in non-domestic work, he thinks it necessary to apologise for having introduced such remarks, as not, perhaps, strictly within the province of political economy. And when he finds himself similarly induced to observe on the evils of severe and incessant labour, and the benefits of a certain degree of leisure—subjects so momentous to working men, and closely connected with their material as well as moral condition—he pauses and corrects himself, admitting that he should not only be justified in omitting, but perhaps was bound to omit, all considerations which have no influence on wealth. This is the very pedantry of purism; and the purism is not merely exaggerated, it is really altogether out of place. Mill, though, as I believe, he did not occupy firm ground in relation to the constitution of social science, is free from any such narrowness as this:—"For practical purposes," he says, "political economy is inseparably intertwined with many other branches of social philosophy. Except on matters of mere detail, there are perhaps no practical questions, even among those which approach nearest to the character of purely economical questions, which admit of being decided on economical premises alone." This is true; but it is only part of the truth. For purposes of theory as well as of practice, the several branches of social inquiry are inseparably intertwined; and this larger proposition Mill in another place has stated with all the desirable fulness of enunciation, declaring that "we can never understand in theory or command in practice the condition of a society in any one respect, without taking into consideration its condition in all other respects."

Yet, notwithstanding this ample admission, he appears to exhibit some uncertainty of view with respect to the relation of economic studies to general sociology; at least after repeated careful examination of all that he has written on the subject, I confess myself unable to understand exactly the position he occupies. Sometimes he speaks of political economy as being a department "carved" (to use his own expression) "out of the general body of the science of society;" and again he speaks of it as belonging to a subordinate order of speculation to that with which the science of society is conversant—proposing to itself a quite different sort of question, and supplying only a sort of knowledge sufficient for the more common exigencies of daily political practice. The latter view is apparently reflected in the title of his economical treatise, which is called 'Principles of Political Economy, with some of their Applications to Social Philosophy,' a phrase which seems to imply that political economy is not a part of social philosophy at all, but is preparatory and ancillary to it. And it is interesting to observe that it was from this point of view of the study, as preliminary only and intended to prepare the way and provide materials for a true science of society, that Comte, in his correspondence with Mill, encouraged the latter in his project of a special treatise on political economy.

The ground which the economists commonly take up in justifying their one-

sided attitude, is this: they announce that their treatment of every question is partial and incomplete, and that for a real solution all the other elements involved must be taken into account. Political economy, Professor Cairnes tells us, is absolutely neutral as between all particular schemes and systems of social or industrial life. It furnishes, he tells us, certain data that go towards the formation of a sound opinion, but can never determine our final judgment on any social question. Now this systematic indifferentism amounts to an entire paralysis of political economy as a social power capable of producing or confirming in the mass of the community just convictions on the most important of all subjects. How, it may well be asked, are sufficiently fixed and convergent opinions on such matters to be generated in the public mind? How are the scattered lights, supplied by the several partial and one-sided studies of human affairs, to be combined, so as to convey social truth to the understanding, and impress its practical consequences on men's consciences? These queries bring into the clearest light the doctrine I wish to commend to your attention—namely, that what is wanted for this purpose is a study of social questions from all the points of view that really belong to them, so as to attain definite and matured conclusions respecting them—in other words, a scientific sociology, comprehending true economic doctrine, but comprehending also a great deal more.

Even on the special subjects in which purely economic considerations go for most, it will not do to take into account those considerations only. Professor Fawcett, in his recent timely and useful treatise on Free-trade and Protection, finds that he cannot restrict himself, in the treatment of that question, to the economic point of view. "As complaints," he says, "are constantly made by protectionists that their opponents persistently ignore all the results of protection which are not economic, I will be careful to consider those results." And he goes on to maintain the proposition, in which I entirely concur, that protection may produce social and political consequences even far more mischievous than the economic loss it causes to a country. I believe that the most effective weapons against this and other economic errors will often be found in reasons not based on material interests, but derived from a consideration of the higher ends of society, and the ideal of the collective life of the race. And, *à fortiori*, when we have to deal with the larger economic subjects, now rapidly increasing in urgency, which are more immediately in contact with moral conceptions, these questions of the ultimate ends of the social union cannot be left out of sight. This was recognised by Mill, who was open to all noble ideas, and saw that the practical life of mankind cannot be governed by material egoism. In discussing the claims of Communism, he says:—"Assuming all the success which is claimed for this state of society by its partisans, it remains to be considered how much would be really gained for mankind, and whether the form that would be given to life, and the character which would be impressed on human nature, can satisfy any but a very low estimate of the capabilities of the species." Here, you observe, is raised the entire question of the ends of social life; and economic progress is subordinated, as it ought to be, to the intellectual and moral development of humanity.

Mr. Lowe, at the Adam Smith celebration, declared himself not to be sanguine as to the future of political economy; he believes that its great work, which he justly remarks has been rather a negative than a constructive one, has been already accomplished, and that not much more remains to be achieved. Such, indeed, as we have seen, Professor Cairnes declared to be the prevalent idea of the great majority of educated people—that political economy has fulfilled its task by removing impediments to industry; and that it cannot help us—is rather likely to be an obstruction—in the social work which now lies before us. I will not use language so strong; but it does appear to me that either as a fruitful branch of speculation, or as an important source of practical guidance, it will cease to command, or rather will fail to regain attention, unless it be linked in close connection with the general science of society—unless it be, in fact, subsumed under and absorbed into Sociology.

II. The second common error of the political economists since the time of Adam Smith, consists in this, that, mainly by the influence of Ricardo, they have been led to

conceive and present, in a viciously abstract way, the conceptions with which they deal.

Abstraction is, indeed, necessary to all science, being implied in the search after unity amidst variety. The criterion of true or false science lies precisely in the right or wrong institution of the relation between the abstract and the concrete. Now, in matters of human life especially, we have only to carry abstraction far enough in order to lose all hold on realities, and present things quite other than they in fact are; and, if we use these abstractions in the premises of our reasonings, we shall arrive at conclusions, either positively false, or useless for any practical purpose. As Comte remarked, the most fundamental economic notions have been subtilized in the ordinary treatises, till the discussions about them often wander away from any relation to fact, and lose themselves in a region of nebulous metaphysics; so that exact thinkers have felt themselves obliged to abandon the use of some of the most necessary terms, such as *value, utility, production,* and to express the ideas they attach to them by circuitous phrases. I am far from condemning the effort after accuracy of language and well-defined terms; but the endless fluctuations of economists in the use of words (of which numerous examples are given in Senior's Appendix to Whately's 'Logic,' and in Professor Price's recent work) certainly indicate a very general failure to apprehend and keep steadily in view the corresponding realities.

A vicious abstraction meets us on the very threshold of political economy. The entire body of its doctrines, as usually taught, rests on the hypothesis that the sole human passion or motive which has economic effects, is the desire of wealth. "It aims," says Mill, "at showing what is the course of action into which mankind living in a state of society would be impelled if that motive"—except so far as it is checked by aversion to labour, and desire of present indulgence—"were absolute master of all their actions." "So strictly is this its object," he adds, "that even the introduction of the principle of population interferes with the strictness of scientific arrangement." But what is the desire of wealth? It is, as Mr. Leslie says in an article in 'Hermathena,' in which he urges the necessity for a new method in political economy—it is a general name for a great variety of wants, desires, and sentiments, widely differing in their economic character and effect, and undergoing fundamental changes in some respects in the successive periods of society. As moralists, viewing the same abstraction, not as a condition of well-being, but as the root of all evil, "have denounced under the common name of love of wealth, not only sensuality, avarice, and vanity, but the love of life, health, cleanliness, decency, and art, so all the needs, appetites, tastes, aims and ideas which the various things comprehended in the word 'wealth' satisfy, are lumped together in political economy as a principle of human nature, which is the source of industry and the moving principle of the economic world." The motives summed up in the phrase vary in different individuals, different classes, different nations, different sexes, and especially in different states of society; in these last, indeed, the several desires comprehended under the general name follow definite laws of succession. The point Mr. Leslie here insists on is, be it observed, not merely—though that is also true—that the phrase *desire of wealth* represents a coarse and crude generalization in the natural history of man; but that the several impulses comprised under the name assume altered forms and vary in their relative strength, and so produce different economic consequences, in different states of society; and therefore that the abstraction embodied in the phrase is too vague and unreal for use in economic investigations of a really scientific character. The special desire for accumulation, apart from the immediate or particular uses of wealth, is no doubt a principle of social growth which must not be overlooked; but this, too, takes different directions and works to different ends in different stages of social development. All these economic motors require to be made the subjects of careful and extensive observation; and their several forms, instead of being rudely massed together under a common name, should be discriminated as they in fact exist. The consumption, or more correctly the use, of wealth, until lately neglected by economists, and declared by Mill to have no place in their science, must, as Professor Jevons and others now see, be systematically studied in its relations to production

and to the general material well-being of communities. And none of these things can be really understood without correct views of the structure and evolution of society in all its aspects: in other words, we are led back to the conclusion, that they cannot be fruitfully treated apart from general sociology. I have not been able to do more than indicate the leading features of a criticism which I recommend all who are interested in the subject to pursue in its full development in Mr. Leslie's admirable essay.

There is a common economic abstraction, which, by the unsympathetic colour it has given to political economy, has tended, perhaps more than anything else, to repel the working classes from its study. By habitually regarding labour from the abstract point of view, and overlooking the personality of the labourer, economists are led to leave out of account some of the considerations which most seriously affect the condition of the working man. He comes to be regarded exclusively as an agent—I might almost say, an instrument of production. It is too often forgotten that he is before all things a man and a member of society—that he is usually the head of a household, and that the conditions of his life should be such as to admit of his maintaining the due relations with his family—that he is also a citizen, and requires for the intelligent appreciation of the social and political system to which he belongs a certain amount of leisure and opportunity for mental culture. Even when a higher education is now sought for him, it is often conceived as exclusively designed to adapt him for the effective exercise of his functions as a producer, and so is reduced to technical instruction; whereas moral and social ideas are for him, as for all of us, by far the most important, because most directly related to conduct. Labour, again, is viewed as a commodity for sale, like any other commodity; though it is plain that, even if it could be properly so called at all, yet in some particulars, as in the difficulty of local transfer (a family having to be considered), and in the frequent impossibility of waiting for a market, it is quite exceptional amongst commodities. By a further abstraction, the difference of the social vocations of the sexes is made to disappear, in economic as in political reasoning, by means of the simple expedient of substituting for *man* in every proposition *person* or *human being*; and so, by little else than a trick of phraseology, self-support is made as much an obligation of the woman as of the man. It is true that ungenerous sentiment has much to do with the prevalence of these modes of thought; but what it is most suitable to insist on here, is that the science on which they rest, or in which they find justification, is false science. By merely keeping close to facts and not hiding realities under lax generalizations, we shall be led to more humane, as well as truer, conceptions of the proper conditions of industrial life.

It is a characteristic feature of the metaphysical habit of mind (using that phrase in the sense with which Comte has familiarized us) to mistake creations of the speculative imagination for objective realities. Examples of this tendency have not been wanting in the dominant system of political economy. The most remarkable is perhaps furnished by the 'Theory of the Wages Fund.' The history of that doctrine is instructive, but I cannot here enlarge upon it; it may suffice to say that though the so-called wages fund is simply a scientific figment, the only legitimate use of which would be to facilitate the expression of certain relations, it has been habitually regarded as an actual entity, possessing a determinate magnitude at any assigned instant. It is true that Mill gave up this theory, when Mr. Thornton had convinced him of its unsubstantial nature; but, strange to say, even when relinquished by the master, some of the disciples continued to cling to it. Professor Cairnes in his latest work insisted that Mill was mistaken in abandoning it, and it is still taught in some of the elementary manuals —not, I am glad to observe, in that of Professor Jevons, who indeed never adopted it. There are, in my opinion, other quite as illusory economic conceptions which have met with a good deal of acceptance, and have even obtained the sanction of distinguished names. If I do not now enter on an examination of them, it is because I am unwilling that the general views I am desirous of presenting should be lost in a series of special discussions, for which a more suitable opportunity can easily be found.

III. The third prevailing error of the economists—and, with the exception of

the isolation of their study, this is the most serious of all—is that of exaggerating immensely the office of deduction in their investigations.

Deduction has indisputably a real and not inconsiderable place in Sociology. We can sometimes follow the method which Mill calls the direct deductive, that is, we can, from what we know of the nature of man and the laws of the external world, see beforehand what social phenomena will result from their joint action. But, though the economists of the so-called orthodox school recognize no other method, we cannot really proceed far in this way, which is available only in simple cases. Social phenomena are in general too complex, and depend on too manifold conditions, to be capable of such *à priori* determination. In so far as the method can be used, the vital condition of its legitimate employment is the ascertainment of the consilience of the results of deduction with those of observation; and yet such verification from fact of the conclusions of theory, though essential to the admissibility of this process of inquiry, is too often entirely overlooked.

Much more commonly the function of deduction is different from what has just been described, and its relation to observation is inverted. The laws of the economic constitution and movement of society are first obtained by observation, whether directed to contemporary life or to the history of the past. The office of deduction is then to verify and control the inductions which have been arrived at, using for this purpose considerations founded on the qualities of human nature and the external conditions to which society is subjected. Results which could not have been elicited by *à priori* reasoning from the latter data, may, when inductively obtained, be in this way checked and rationalized. The pretension of the economists, formally set forth in Senior's treatise, to deduce all the phenomena of the industrial life of communities from four propositions, is one that cannot be sustained. But conclusions derived from observation may be placed in relation with the laws of the world and of human nature, so far at least as to show that they contradict nothing we know respecting those laws. This method, in which inductive research preponderates, and deduction takes a secondary place as means of verification, is the really normal and fruitful method of sociological inquiry.

But the method of Sociology must be not only inductive, but historical; and by the latter name it may best be characterised. By this is meant, not merely that it finds the materials for its studies in the general field of human history: we mean further that it institutes a comparison of the successive states of society in order to discover the laws of social filiation—a process similar in principle to the biological comparison of organisms of different degrees of development. If we followed exclusively the *à priori* method, in (for example) economic research, and sought to infer the economic facts of life from the nature of the world and man, we could arrive only at one determinate order of things, whilst we know that in reality the economic organization and functions of society vary in time according to definite laws of succession. Mr. Lowe, indeed, will have it that "political economy is founded on the attributes of the human mind, and nothing can change it;" which means, I suppose, that its formulas must always correspond with the phenomena. But how can this view be reconciled with the now ascertained fact, that society has passed through states in which the modern economic constitution was so far from existing, that property did not belong to the individual, but to the community? The *à priori* method, in fact, overlooks what is the main agency in the social movement—namely, the accumulated influence of anterior on subsequent generations of mankind; an influence too complex to be estimated deductively. Every department of social life, and amongst the rest the industrial system, undergoes transformation—not arbitrarily indeed, but in accordance with law; and if we wish to understand any of those departments, we must study its transformations, considering each successive form in relation to all the preceding and contemporary conditions.

There is, indeed, no more important philosophical theorem than this: that the nature of a social fact of any degree of complexity cannot be understood apart from its history. "Only when its genesis has been traced," says Mr. Herbert Spencer, "only when its antecedents of all orders have been observed in their co-operation, generation after generation, through past social states—is there reached that interpretation of a fact which makes it a part of sociological science." To understand,

for example, the true meaning of the trade societies of modern times, so important an object of economic study, "we must," he says, "go back to the older periods when analogous causes produced analogous results." And facts of this order, he adds, "must be studied not merely in their own successive forms, but in relation to the other phenomena of their time—the political institutions, the class distinctions, the family arrangements, the modes of distribution and degree of intercourse between localities, the amounts of knowledge, the religious beliefs, the morals, the sentiments, the customs." These considerations all point to the historical method, and, I may add, they all confirm what I have already urged, that the economic phenomena of society cannot be isolated from its other aspects. When our object is not the explanation of any past or present fact, but the prevision (within possible limits) of the future, and the adoption of a policy in relation to that future, our guide must still be the historic method, conceived as indicating, from the comparison of successive states, the general tendency of society with respect to the phenomenon considered, and the agencies which are in course of modifying existing systems. "Legislative action of no kind," again says Mr. Spencer, "can be taken that is not either in agreement with or at variance with the processes of national growth and development as naturally going on." We can by judicious action modify in their special mode of accomplishment or in the rate of their development, but cannot alter in their fundamental nature, the changes which result from the spontaneous tendencies of humanity. An attempt to introduce any social factor which is not essentially conformable to the contemporary civilization, will result, if not in serious disturbance, at least in a mere waste of effort. Any proposal of social action, therefore, should repose on a previous analysis of those spontaneous tendencies, and this is possible only by the historic method. Let me give an example from an economic subject which happens just at present to offer a special interest. Attention has been called by Sir Henry Maine to the general law that property in land originally belongs, not to individuals, nor even to families in the modern sense, but to larger societies, and that in the progress of mankind there is a natural movement from common to separate ownership. This historical result has been elaborated by a number of independent inquirers; and M. de Laveleye in a work of great research has brought together a vast mass of evidence, both establishing the main fact, and exhibiting the varied features which the common evolution has assumed in different countries. There is much that is attractive in particular sides of this early organization of territorial property, and M. de Laveleye has yielded to the charm, so far as to regret its disappearance in the developed communities of the West, though he stops short of recommending what others have suggested—namely, a return to the primitive constitution, by replacing the commune in the possession of the soil. Indeed, he himself, by establishing the progressive spontaneous tendency of society towards individual property, shows such a project to be a dream, and banishes it from the field of practical economic policy. From the general appearance of this collective ownership in an early stage of society, it is sometimes argued that it is a *natural* system; but the historic method shows that it is just as natural that it should disappear at a more advanced stage. Serving useful ends in the former period, it becomes in the latter an obstruction to progress by stereotyping agricultural art, and impeding that individual initiative which is an indispensable condition of social improvement. The safe prediction is that the Swiss *Allmend*, the Russian *Mir*, and other forms of collective ownership will disappear, and that personal appropriation will become the universal rule. The social destination of property in land, as of every species of wealth, will be increasingly acknowledged and realized in the future; but that result will be brought about, not through legal institutions, but by the establishment and diffusion of moral convictions.

There have been great differences of opinion as to the method of economic inquiry pursued by Adam Smith. Mr. Lowe insists that his method was deductive—that he had the unique merit of having raised the study of a branch of human transactions to the dignity of a deductive science. At the same celebration at which this opinion was put forward, Professor Thorold Rogers expressed his surprise that anyone should entertain such a view. It seemed to him clear that Adam Smith was pre-eminently an inductive philosopher. Mr. Rogers has edited

the 'Wealth of Nations,' and in doing so has verified all the references; and what strikes him is the extraordinary wideness of the reading from which Smith drew his inferences. The work, he says, is full of facts. It is interesting to observe that David Hume made just the same remark on the book at the time of its publication:—"It has depth," he said, "and solidity, and acuteness, and is so much illustrated with curious facts, that it must take the public attention."

Of the two views thus advanced by Mr. Lowe and Mr. Rogers, the latter seems to me much the more correct. That the master tendency of Smith's intellect was the deductive, or that it is at the deductive point of view that he habitually places himself, seems to me plainly at variance with fact. Open his book anywhere, and read a few pages; then do the same with Ricardo's principal work, and observe the difference of the impression produced. Under the guidance of Ricardo you are constantly, not without misgivings, following certain abstract assumptions to their logical results. In Smith you feel yourself in contact with real life, observing human acts and their consequences by the light of experience. Of course deduction is not wanting; but it is in the way of explanation; the facts are *interpreted* from the nature and circumstances of men in general, or particular groups of men. Sagacious observation and shrewd comment go hand in hand.

Adam Smith, besides giving generally a large place to induction, opened several lines of interesting historical investigation, as notably in his Third Book, which contains a view of the economic progress of modern Europe as shaped by political causes. But historic inquiry was neglected by his successors, with a partial exception in the case of Malthus, and the *à priori* method became dominant chiefly by the influence of Ricardo. Professor Price objects to this method as too scientific; but, as Mr. Leslie has said, what ought to be alleged respecting it is that it is unscientific, because ill adapted for the successful investigation of the class of phenomena with which it deals. Setting out from propositions involving the loose abstractions of which I have spoken, it arrives at conclusions which are seldom corrected by the consideration of conditions which were at first, for simplicity, omitted in the premises. And these conclusions can in general not be directly confronted with experience for the purpose of verification, for they are hypothetical only; they give us, not the resultant phenomenon, but only a tendency of a certain character, which will be one component of the resultant.

I am not concerned nor disposed to deny that useful general indications have been gathered by inference of this kind. But it is evidently a very unsafe process, even in purely economic matters, especially when consequences are pushed into any degree of detail. Careful thinkers have a profound distrust of lengthened deductions in economic inquiries. When it is argued that A must lead to B, and B again to C, and so on through a long chain of results, they assume in self-defence a sceptical attitude of mind, and often feel more than half convinced that what is going on is a feat of logical sleight of hand. And this suspiciousness is, I think, reasonable; for we are not here on the same ground as in mathematics, where protracted deductions are always safe, because we can be sure that we have before us at every step all the determining data, and each proposition successively used is universally true. But as the most that the economist can affirm is a set of tendencies, the certainty of his conclusions is plainly weakened in a rapidly increasing ratio by the multiplication of links, there being always a possibility that the theorems applied in the course of the demonstration may be subject to special counteractions or limitations in the case we are considering.

I observed before that Mill betrayed some uncertainty of view as to the precise relation of economic inquiries to general sociology. As to the proper method of the social science also, he appears to me not strictly consistent with himself. That method he declares, in so many words, to be the direct deductive. Yet elsewhere he as plainly agrees with Comte, that in the general science of society, as distinguished from its separate departments, nothing of a scientific character is possible except by the inverse deductive—as he chooses to call the historical—method. In one place he seems to assert that the general course of economic evolution could be predicted from the single consideration of the desire

of wealth. Yet again he admits that no one could determine *à priori* from the principles of human nature and the general circumstances of the race the order in which human development takes place. Now this involves the conclusion, that the laws of economic progress—like all dynamic laws of Sociology—must be ascertained by observation on the large scale, and only verified by appeal to the laws of the external world and human nature; in other words, that the right method for their study is the historical.

I hope it is not inconsistent with a profound respect for the eminent powers and high aims of Mill, to say that he appears to me never to have extricated himself completely from the vicious habits in regard to sociological method impressed on him by his education. His father had the principal part in the formation of his mind in his early years. Now whatever were the intellectual merits of James Mill, his mode of thinking on social subjects was essentially metaphysical, as opposed to positive. Through him, as well as directly, John Mill came under the influence of Bentham, of whom, whilst fully recognizing his services, we may truly say that he was one of the most unhistorical of writers, building most, I mean, on assumed *à priori* principles, and sympathizing least with the social past, in which he saw little except errors and abuses. It is strong evidence of the natural force of Mill's intellect that he more and more, as he advanced towards maturity, shook himself loose of the prejudices of his early *entourage*. On every side, not even excluding the æsthetic, he grew in comprehensiveness, and his social and historic ideas in particular become wider and more sympathetic. The publication of the letters addressed to him by Auguste Comte has revealed more fully, what could already be gathered from his writings, that the study of that eminent thinker's first great work happily concurred with and aided his spontaneous tendencies. Hence in his economic studies he broke away in many respects from the narrow traditions of the reigning English school, and by opening larger horizons and discrediting rigid formulas, did much to prepare the public mind for a more complete as well as truly scientific handling of these subjects. But though the interval between his father and himself represents an immense advance, yet never in regard to method did he, in my opinion, attain a perfectly normal attitude. Whilst in his 'Logic' he criticized with just severity what he, not very happily, calls the geometrical mode of philosophizing practised by the Benthamites in political research, he approves what is essentially the same course of proceeding in economic inquiry; and, whilst protesting against the attempt to construct a special science of the political phenomena of society apart from general sociology, he yet, with whatever restrictions and qualifications, accepts the separate construction of a science of its industrial phenomena. His ambition in his work on political economy was, as may be seen from the preface, to replace the 'Wealth of Nations' by a treatise which, whilst more uniformly correct on points of detail, should be in harmony with contemporary social speculation in the widest sense. Admitting fully the great merits of the book, I yet must hold that, chiefly from the absence of any systematic application of the historic method, he has not succeeded in attaining this end. The presentation of what is solid and permanent in the work of the economists, in relation with the largest and truest views of general sociology, is, in my judgment, a task which still remains to be accomplished.

The tendencies of the new school with respect to method are sufficiently indicated by the names of the Realistic and the Historical by which it designates itself. It declares, in the words of Brentano, the description of political economy by the so-called orthodox writers as a hypothetic science, to be only a device to cloak its dissonance with reality; and affirms that much of the current doctrine is made up of hasty generalizations from insufficient and arbitrary premises. It sets out, says Held, from observed facts, and not from definitions, which often serve only to mask foregone conclusions. It aims at describing objectively existing economic relations, not as immutable necessities, but as products of a gradual historical development in the past, and susceptible of gradual modification in the future. "Its philosophical method," says Mr. Leslie, "must be historical, and must trace the connection between the economical and the other phases of national history." In these tendencies the rising school seems to me to be in har-

mony with all that is best in the spirit of the most advanced contemporary thought.

IV. Lastly has to be noticed the too absolute character of the theoretic and practical conclusions of the political economists. It follows (as I have already indicated) from their *à priori* and unhistoric method that they arrive at results which purport to apply equally to all states of society. Neglecting the study of the social development, they tend too much to conceive the economic structure of society as fixed in type, instead of as undergoing a regular modification in process of time, in relation to the other changing elements of human condition. Similar consequences arose in other branches of sociological inquiry from the prevalence of unhistoric methods. But reforms have been largely carried into effect from the increasing recognition of the principle, that the treatment of any particular aspect of society must be dominated by the consideration of the general contemporary state of civilization. Thus, in jurisprudence there is a marked tendency to substitute for the *à priori* method of the Benthamites a historical method, the leading idea of which is to connect the whole juristic system of any epoch with the corresponding state of society; and this new method has already borne admirable fruits, especially in the hands of Sir Henry Maine. Again, the old search after the best government, which used to be the main element of political inquiry, is now seen to have been radically irrational, because the form of government must be essentially related to the stage of social development and to historic antecedents, and the question, what is the best? admits of no absolute answer.

Mill admits that there can be no separate science of government; in other words, that the study of the political phenomena of society cannot be conducted apart, but must, in his own words, stand part of the general science of society, not of any separate branch of it. And why? Because those phenomena are so closely mixed up, both as cause and effect, with the qualities of the particular people, or of the particular age. Particular age must here mean the state of general social development. But are not economic phenomena very closely bound up with the particular state of development of the society which is under consideration? Mr. Bagehot, indeed, took up the ground that political economy is "restricted to a single kind of society, a society of competitive commerce, such as we have in England." And Mill himself, whilst stating that only through the principle of competition, as the exclusive regulator of economic phenomena, has political economy any claim to the character of a science, admits that competition has, only at a comparatively modern period, become in any considerable degree the governing principle of contracts; that in early periods transactions and engagements were regulated by custom, and that to this day in several countries of Europe, in large departments of human transactions, custom, not competition, is the arbiter.

The truth is, that in most enunciations of economic theorems by the English school, the practice is tacitly to presuppose the state of social development, and the general history of social conditions, to be similar to that of modern England; and when this supposition is not realised, those theorems will often be found to fail.

The absolute character of the current political economy is shown, not only by this neglect of the influence of the general social state, but in the much too unlimited and unconditional form which is given to most of its conclusions. Mr. Fawcett has, in his latest publication, animadverted on this practice; thus, he points to the allegation often met with, that the introduction of machines must improve the position of the workman, the element of time being left out of account; and the assertion that the abolition of protection in the United States could not injure the American manufacturer. But this lax habit cannot, I believe, be really corrected apart from a thorough change of economic method. As long as conclusions are deduced from abstract assumptions, such as the perfectly free flow of labour and capital from one employment to another, propositions which only affirm tendencies will be taken to represent facts, and theorems which would hold under certain conditions will be announced as universally true.

The most marked example the economists have afforded of a too absolute conception and presentation of principle, both theoretical and practical, is found in the doctrine of *laissez faire*. It might be interesting, if time permitted, to follow

its history in detail. First inspired by *à priori* optimistic prepossessions, it long served a useful purpose as an instrument of combat against the systematic restrictions with which a mistaken policy had everywhere fettered European industry. But, from the absolute manner in which it was understood and expressed, it tended more and more to annul all governmental intervention in the industrial world, even when intended not to alter the spontaneous course of industry, but only to prevent or remedy the social injustices and other mischiefs arising from the uncontrolled play of private interests. Experience and reflection, however, gradually surmounted the exaggerations of theory. The community at large became impatient of *laissez faire* as an impediment and a nuisance; statesmen pushed it aside, and the economists, after long repeating it as a sacred formula, themselves at last revolted against it. So far has the reaction proceeded, that Professor Cairnes has declared the doctrine implied in the phrase—namely, that the economic phenomena of society will always spontaneously arrange themselves in the way which is most for the common good—to be a pretentious sophism, destitute of scientific authority, and having no foundation in nature or fact.

Let me now recapitulate the philosophical conclusions which I have been endeavouring to enforce. They are the following:—

(1) That the study of the economic phenomena of society ought to be systematically combined with that of the other aspects of social existence; (2) That the excessive tendency to abstraction and to unreal simplifications should be checked; (3) That the *à priori* deductive method should be changed for the historical; and (4) That economic laws and the practical prescriptions founded on those laws should be conceived and expressed in a less absolute form. These are, in my opinion, the great reforms which are required both in the conduct of economic research, and in the exposition of its conclusions.

I am far from thinking that the results arrived at by the hitherto dominant economic school ought to be thrown away as valueless. They have shed important partial lights on human affairs, and afforded salutary partial guidance in public action. The task incumbent on sociologists in general, or such of them as specially devote themselves to economic inquiries, is to incorporate the truths already elicited into a more satisfactory body of doctrine, in which they will be brought into relation with the general theory of social existence—to recast the first draughts of theory, which, however incomplete, in most cases indicate real elements of the question considered—and to utilize the valuable materials of all kinds which their predecessors have accumulated. Viewed as provisional and preparatory, the current political economy deserves an approbation and an acceptance to which I think it is not entitled, if regarded as a final systematization of the industrial laws of society.

Returning now from our examination of the condition and prospects of economic study in the general field of human knowledge to the consideration of its position in this Association, what seems to follow from all I have been saying? I do not take into account at all the suggestion that that study should be removed from what professes to be a confederation of the sciences. As has been well said, the omission from the objects of this body of the whole subject of the life of man in communities, although there is a scientific order traceable in that life, would be a degradation of the Association. If the proper study of mankind is man, the work of the Association, after the extrusion of our Section, would be like the play with the part of the protagonist left out. What appears to be the reasonable suggestion, is that the field of the Section should be enlarged, so as to comprehend the whole of Sociology. The economic facts of society, as I have endeavoured to show, cannot be scientifically considered apart; and there is no reason why the researches of Sir Henry Maine, or those of Mr. Spencer, should not be as much at home here as those of Mr. Fawcett or Professor Price. Many of the subjects, too, at present included in the artificial assemblage of heterogeneous inquiries known by the name of Anthropology, really connect themselves with the laws of social development; and if our Section bore the title of the Sociological, studies like those of Mr. Tylor and Sir John Lubbock concerning the early history of civilization would find in it their most appropriate place. I prefer the name Sociology to that

of Social Science, which has been at once rendered indefinite and vulgarized in common use, and has come to be regarded as denoting a congeries of incoherent details respecting every practical matter bearing directly or remotely on public interests, which happens for the moment to engage attention. There are other Societies in which an opportunity is afforded for discussing such current questions in a comparatively popular arena. But if we are to be associated here with the students of the other sciences, it is our duty, as well as our interest, to aim at a genuinely scientific character in our work. Our main object should be to assist in fixing theoretic ideas on the structure, functions, and development of society. Some may regard this view of the subject with impatience, as proposing to us investigations not bearing on the great and real needs of contemporary social life. But that would be a very mistaken notion. Luciferous research, in the words of Bacon, must come before fructiferous. "Effectual practice," says Mr. Spencer, "depends on superiority of ideas; methods that answer are preceded by thoughts that are true." And in human affairs, it is in general impossible to solve special questions correctly without just conceptions of *ensemble*—all particular problems of government, of education, of social action of whatever kind, connect themselves with the largest ideas concerning the fundamental constitution of society, its spontaneous tendencies, and its moral ideal.

I have as yet said nothing of Statistics, with which the name of this Section at first exclusively connected it, and which are still recognized as forming one of its objects. But it is plain that though Statistics may be combined with Sociology in the title of the Section, the two cannot occupy a co-ordinate position. For it is impossible to vindicate for Statistics the character of a science; they constitute only one of the aids or adminicula of science. The ascertainment and systematic arrangement of numerical facts is useful in many branches of research, but, till law emerges, there is no science; and the law, when it does emerge, takes its place in the science whose function it is to deal with the particular class of phenomena to which the facts belong. We may arrange meteorological facts in this way as well as sociological; and, if doing so helps us to the discovery of a law, the law belongs to meteorology: and, in the same manner, a law discovered by the aid of statistics would belong to sociology.

But though the character of a science cannot be claimed for Statistics, it is obvious that if the views I have advocated as to the true nature and conditions of economic study should prevail, the importance of statistical inquiries will rise, as the abstract and deductive method declines in estimation. Senior objected to the saying that political economy is *avide de faits*, because, according to him and the school of Ricardo in general, its work was mainly one of inference from a few primary assumptions. But if the latter notion is given up, every form of careful and conscientious search after the realities of the material life of society, in the present as in the past, will regain its normal importance. This search must, of course, be regulated by definite principles, and must not degenerate into a purposeless and fortuitous accumulation of facts; for here, as in every branch of inquiry, it is true that "*Prudens interrogatio est dimidium scientiæ.*"

I do not expect that the views I have put forward as to the necessity of a reform of economic studies will be immediately adopted either in this Section or elsewhere. They may, I am aware, whilst probably in some quarters meeting with at least partial sympathy, in others encounter determined hostility. And it is possible that I may be accused of presumption in venturing to criticize methods used in practice, and justified in principle, by many distinguished men. I should scarcely have undertaken such an office, however profoundly convinced of the urgency of a reform, had I not been supported by what seemed to me the unanswered arguments of an illustrious thinker, and by the knowledge that the growing movement of philosophic Europe is in the direction he recommended as the right one. No one can feel more strongly than myself the inadequacy of my treatment of the subject. But my object has not been so much to produce conviction as to awaken attention. Our economists have undeniably been slow in observing the currents of European thought. Whilst such foreign writers as echo the doctrines of the so-called orthodox school are read and quoted in

England, the names of those who assume a different and more independent attitude are seldom heard, and their works appear to be almost entirely unknown. But the fence of self-satisfied routine within which in these countries we formerly too often entrenched ourselves is being broken down at every point; and no really vital body of opinion can now exist abroad without speedily disturbing our insular tranquillity. The controversy, therefore, as to the methods of economic research and its relations to Sociology as a whole, cannot long be postponed amongst us. It has, in fact, been already opened from different sides by Mr. Leslie and Mr. Harrison, and it is desirable that it should arrive as promptly as possible at a definitive issue. If I have done anything to-day to assist in launching this great question on the field of general English discussion, the purpose I have set before me will have been abundantly fulfilled.

The following Papers were read:—

1. *Report of Anthropometric Committee.* See Reports, p. 152.

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2. *On Canadian Statistics.** *By* A. E. Bateman, *F.S.S.*

The author said that these were very much less widely known than those of our Australian colonies. In the province of Quebec, or as it was called New France, the population in 1665 was 3,215; in 1695, 13,695; in 1726, 29,396; in 1736, 39,000. The census of Ontario and Quebec, taken in 1861, was very much in excess of the real numbers, chiefly on account of the double entry of persons not sleeping at home on the night of the census. One result was that the census of 1871 failed to show the increase that had been expected. The rate of mortality was said to be 14 per 1,000, considered to be much below the truth; but, taking the death rate at 21 and the birth rate at 35 per 1,000, and allowing for the increase by recorded immigration, the estimated population of the Dominion of Canada was now something over four millions and a quarter. In the ten years since the Dominion was formed, the imports had increased from fifteen millions to more than twenty millions sterling; the exports from twelve to sixteen millions sterling. In the last two or three years there had been a falling off, but when the present commercial depression had passed away, he believed there would be a large development of the meat trade to this country. The total tonnage of seagoing vessels was six millions. This did not include the coasting traffic between the several provinces. There were, in 1871, 180,000 persons employed in manufacturing industries, in receipt of wages to the amount of eight millions sterling. The capital invested was 16 millions, and the value of last year's produce was 46 millions. As to the deposits in Government Savings Banks, these, which ten years ago were little over a quarter of a million, were now a million and a half. The railways were not prosperous, owing to the great competition between railways and canals. They had cost 68 millions. Their income was four millions, and their expenditure about three and a quarter millions, leaving three-quarters of a million—sufficient to pay four or five per cent. on the bonded debt, but leaving little for the ordinary or preference shareholder, or the Government or municipal advances.

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3. *How to meet the Requirements of Population displaced by Artizans' Dwellings Act.*† *By* Sir James Watson.

As the question must occur to every local authority proposing to put this Act in force 'How are we to provide for the population displaced by the pulling down of old

* The full text of this paper will be published in the 'Statistical Society's Journal' for December 1878.

† Published *in extenso* for a few private friends.

houses'—the author thought that a sufficient answer had been given to this question by the proceedings which took place at Glasgow, where the Corporation obtained an Act in 1866 for the same purposes as that for which the Artizans Dwelling Act was many years afterwards procured. This Act led to large purchases of property by the Corporation, under the name of City Improvement Trustees. As soon as it became known that these large purchases of blocks of houses had been made for the purpose of clearing them away, and that there would consequently be a great demand for house accommodation, builders immediately commenced the erection of workmen's houses, and to such an extent has this been carried, that at December last, while no less than 31,057 persons have been displaced by the removal of old buildings during the ten years the improvement trust had been in operation, houses have been erected, not only sufficient to accommodate those displaced, but greatly beyond it. These trustees were in no hurry in pulling down the houses they had purchased, and did not begin such operations for about two and a half or three years from the commencement of their proceedings, so that sufficient time was given for the erection of new buildings. It may, therefore, be reasonably assumed that a like result will follow to all local authorities in similar circumstances. Altogether, however, these operations have been effected with great benefit to the public, and to all who could afford to pay a small increase of rent for a better house; yet it is not to be concealed that it has been attended with considerable hardship to such as are too poor to pay an increased rent in an improved locality. In Glasgow a considerable amount of accommodation has been procured for this class in consequence of a number of tradesmen, with their families, removing from houses in localities not of the poorest kind to those newly erected and better situated, and thus leaving those from which they have removed to this poorer class. These two outlets, though important, have not in Glasgow been found sufficient to meet all the requirements, and accordingly recourse has been had by the Corporation to the erection of model lodging-houses. The peculiar construction of these is worthy of attention. The accommodation given to each lodger is a comfortable bed, separate from others. There is apparatus necessary for washing, &c., a bath-room, a comfortable large sitting-room, to which all the lodgers are admitted, cooking apparatus, and fire and gas. The charge is $3\frac{1}{2}d.$ and $4\frac{1}{2}d.$ per night, or 1*s.* 9*d.* or 2*s.* 3*d.* per week. Games of various kinds are allowed in the evening, and there are newspapers and a library for the use of the inmates; a chaplain is attached to each house, and Divine worship is performed every Sabbath. The success which has attended the houses already opened is very gratifying; for although they have been erected at a time when ground and building was at an inflated price, and when time was required to make them known, so as to procure adequate numbers, they have yielded a fair return on the money spent upon them, viz., $5\frac{1}{4}$ per cent. per annum.

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4. *On the Boarding-out of Pauper Children.* *By* MISS ISABELLA M. TOD.

The most conspicuous opponent of the boarding-out system repeatedly and earnestly deplores the mischiefs of all kinds to which children are exposed in workhouses. The discontent and even alarm which such a conviction created led to the establishment of the English District Schools. Undeniably the scheme had certain advantages. But after many years' experience, the opinion of most of those who have watched it minutely is that this plan also has failed, and has failed precisely because, with all possible external advantages, it has inherited the wholesale workhouse mode of treatment, and, therefore, has reproduced its effects upon the children. Various charitable associations in England had always been in the habit of finding rural homes for some of their children, but the existence of the district schools (although even they are only available for a minority of the pauper children), probably prevented philanthropists from quickly perceiving their need of similar care. The present movement in that direction may be said to have begun with the exertions of Mrs. Archer, Miss Boucherett, the Misses Hill, and other ladies, about

fifteen years ago. In Scotland boarding out has, in one form or another, been practised for a century or more as a mode of relief. In Ireland, as the Poor-law itself is a very modern affair, it is not, in the early stages, to anything done by the authorities, but to the action of voluntary charities, that we have to look for experience. Warned by the errors of the old Charter Schools, which had just been closed, the Protestant Orphan Society from the first eschewed large buildings and mechanical arrangements, and placed the children in families in the country. The success of this institution is beyond dispute, and as it deals with hundreds at a time, the scale is sufficiently large to be an excellent test of efficiency. In a similar manner many Roman Catholic orphanages and institutes—such as those of St. Joseph and St. Bridget—have constantly boarded out the children in their care among farmers and others in the country with the best results. The Presbyterian Orphan Society, with the working of which I am best acquainted, has been about ten years in operation, and it, also, makes the placing of the children in suitable families its central object. Not till 1862 were Irish guardians empowered to board young children out, and that only up to the age of five years, except in special cases. Power was afterwards obtained to board out the children until ten years of age. At this point it remained until 1876, when a bill was introduced and carried by Mr. O'Shaughnessy, M.P. for Limerick, to extend the age to thirteen; and those unions—decidedly the majority, and also the most important—which had already adopted the system, gladly availed themselves of the permission. It was evident, however, that if boarding out was to be substituted on a large scale for the false system which had grown up care would have to be taken that the supervision by educated people, which was connected with it when set in operation by charitable associations, should be continued in a satisfactory and permanent manner when set in operation by the guardians. It needs sound good sense and experience, as well as good will, to select the right foster-parents in each case and to meet with advice, encouragement, or warning the emergencies which arise from time to time. This is the proper work of the ladies who undertake to assist in boarding out. The State is composed of men and women, and has both masculine and feminine duties. The forgetting of this truth led to hideous results for thousands of unhappy children; and now that attention is directed to it, it is not a matter of choice whether ladies will offer to help, or guardians accept their offer, but a matter of plain duty. It is a cause of congratulation that such a committee has just been formed in Dublin to look after children boarded out from the metropolitan unions. The boarding-out system rescues children from artificial conditions under which nothing living could thrive, and secures for its clients a home—friends, parents, brothers, and sisters; school teaching—which becomes a pride and a pleasure, instead of a meaningless drudgery—and religious instruction which is blended with tenderness, instead of a dry form which *might* inspire awe, but *could* not inspire love. This surely is work in which the place of women is evident and essential.

FRIDAY, AUGUST 16, 1878.

The following Papers were read:—

1. *On the Condition of Small Farmers, and their Position with reference to the Land Question.** *By* MURROUGH O'BRIEN.

Ireland is a country of large estates and small farms. There are 300,000 farms the annual value of which is less than 10*l.* each; and the average size of farms of all kinds is under thirty acres.

Thirty-three per cent. of the population are engaged in agriculture, while in England the percentage of agriculturists is thirteen.

Peasant farming in Ireland differs from peasant farming in other parts of Europe, in that the occupiers hold almost universally as tenants from year to year. They are thus subjected to continually increasing rents, the demand for which causes discontent and bad farming, and discourages improvement.

Tenants in Ireland usually supply all buildings, and make whatever improvements are necessary; yet they frequently have to pay increased rent on account of the additional value they have given to their farms. This system tends to make the interests of landlord and tenant more antagonistic than in England.

Rents have always been high in Ireland, and the tendency in settling them is steadily against the tenant; although the increase in the value of land is seldom due to any expenditure of capital by the landlord.

As a consequence, largely affecting for evil the whole nation, the house accommodation of the labouring classes is exceedingly bad. In rural districts there are 148,200 cabins with only one room each. On small farms it does not pay the landlord to build, and yearly tenants can scarcely be expected to build and improve as they would if they were owners.

On small plots purchased under the Bright clauses of the Church and Land Acts remarkable improvements have been noticed. Farmers have built or permanently improved their homesteads; labourers have built themselves substantial cottages; industry has been increased. This points to the settlement of the land question that has universally been recommended by economists, viz., free trade in land, and facilitating occupiers in becoming owners, but "not by means coercive or unjust." Every other solution has involved litigation between landlord and tenant, and has failed to give protection for improvements. It is impossible to reconcile the interests of landlords and tenants; and as long as ownership and occupation are dissevered it is impossible that the land can be cultivated as it should be and the condition of the people be really improved.

There are millions of acres to be reclaimed in Ireland, and a want of, and a desire for, better houses throughout the whole country, yet there is a general complaint that there is no employment. The wages of ordinary labourers are very low, and insufficiently supply the necessaries of life. The want of employment still existing is largely due to the tenure of land, which is such that the landowner cannot make the necessary improvements, and the tenant, if he makes them, is liable at any time to have the fruit of his expenditure wholly or in part appropriated by an increase of his rent. The position with regard to the land question is this: It is the general custom that small farmers should build and maintain their own houses, make and preserve all improvements. Practically the landlord cannot enter

* This paper is published *in extenso* in the 'Journal of the Statistical and Social Inquiry Society of Ireland.'

on the land to do it even if he wished. If the landlord were to provide the buildings which are needed on the small farms, the general value of his estate would not be increased: for the land would not be rendered more directly productive, and he would obtain no return for his outlay. The tenant builds because a house is as necessary to him as clothes or food; it adds to his health and comfort, and in proportion to his comfort and ease is the strength and wealth of the nation increased. The expenditure by tenants on small farms often exceeds the value of the fee-simple. Improvements and reclamation on small farms is necessarily done little by little. A record of such improvements cannot be kept by farmers, and to file them under the sixth section of the Land Act is impracticable. The Land Act (section 4) implies that after the lapse of an uncertain time the improvements made by the tenant should become landlord's property. This is contrary to the natural dictates of justice. The Land Act places no limit to the rent that may be demanded of a tenant. In revaluation of estates the value of the tenant's improvements cannot be satisfactorily eliminated, and the occupier is always liable to a rent placed on his own improvements. Great complaints and discontent exist on this ground—not without reason, as appears from the evidence of the senior judge of the Landed Estates Court. This liability to continually increasing rents checks improvements, and operates as an uncertain and capricious tax on the tenants' capital. No law can fix or limit rents without committing an injustice, and if such a law were passed it might be evaded. The scheme recommended in 1866 by Mr. Bright is the only economical solution of the land question. The partial trial it has had has been most satisfactory; its extension has been recommended by a Select Committee of the House of Commons; and accompanied by a simple system of land transfer, the best results may be expected from a scheme such as this.

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2. *The Creation of a Public Commission to purchase Land for Resale to Occupiers in Ireland.* *By* FRANCIS NOLAN.

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3. *Suggestions for a Bill to regulate Sales of Property.* *By* JAMES H. MONAHAN, *Q.C.*

There is no legal topic more closely connected with economic science than sales of property. Certainly, there is no other single legal subject where the materials for rational legislation are more rich and abundant, nor where a systematic arrangement of these materials is more urgently needed; for the great work of reducing our chaotic *corpus juris* to order. The Judicature Acts constitute a stride in advance towards this desirable achievement. The introduction and reception of Sir J. F. Stephens' Criminal Code is also a most important step gained. And the debate and the division on Mr. Potter's Real Estate and Intestacy Bill is also encouraging to those who desire the substitution of rational and intelligible rules for the survival of feudalism, still permitted to continue to exist in our law. The introduction of Sir J. F. Stephens' Bill has naturally evoked the usual objections from those who do not believe in codification; but I should think that most honest litigants who have had practical experience of protracted litigation will be inclined to believe Mr. Carlyle when he says—"Unfortunate mortals do want to have their bits of lawsuits settled and have on trial found even the ignorant Code Napoleon a mighty benefit in comparison with none." And we have again heard recently, as we have often heard before, that "you can codify rules, but it is impossible to codify principles." One asks, naturally, what then is meant by "a principle," when it is said that "you cannot codify principles?" If the expression "a legal principle" means anything intelligible, surely a legal principle can be stated in plain English, and nothing more is wanted to fit a legal principle for its proper place in a code. In truth, the statement of a legal principle is no more than a compendious description of a general characteristic of the conduct of persons who act in conformity with legal rules. And there is certainly no insuperable difficulty in the way of shaping such descriptions, once legal rules are known.

Sales of property depend upon the branch of the general principle of ownership conversant with powers of disposing of property, and the branch of the general principle of veracity dealing with contracts. I have elsewhere described these general principles fully,* and there is no difficulty in the way of stating in a moderate compass the applications of these principles to sales. This has been already partly accomplished by the Indian Contract Act of 1872; but it is to be wished that the framers of that Act had confined the meaning of the term "property" to "the thing owned," and not also, as in sec. 78, employed "property" to signify "ownership."

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4. *On the Application of Copyhold Enfranchisement to long Leases in Ireland, the assimilation of Chattel and Freehold Succession, and the simplification of Transfer of Land.* By J. H. Edge.

The report of the Committee of the House of Commons on the working of the Bright clauses of the Irish Land Act of 1870, has brought out in a glaring manner some anomalies and defects in the tenure of land in Ireland. The committee, in fact, attribute the break down in the working of these clauses in a great measure to the expense and delay attending the transfer of land from one individual to another, or from the State to a private purchaser; and the report evidently shows forebodings of difficulties to arise hereafter from the same source. Whatever diversity of opinion may exist on such questions as the expediency of creating a peasant proprietary, or the necessity of giving fixity of tenure to the farming class, I think all people will agree with me that if one individual chooses to contract with another to sell him an estate, the costs of transfer ought to be reduced to a minimum. How to do so, and to what extent it can be done, are the problems to solve. The great end to which the public would strive, if they only knew how, would be to make the transfer of land as cheap and speedy as that of ordinary personal property, and it has been powerfully urged that this can be done. It has been asserted that if you can establish a complete registry for shares of ships, you can do the same for shares in land, and that by an easy method transfers in a registry office can be accomplished. I do not think that the question can be pushed to this limit. I think there are essential differences between land and every other marketable commodity, which would prevent its accomplishment, as in every settled country the very nature of land necessitates a division of interests which does not exist in other property. In addition to what I may call the inevitable complication attached to the title of land, family pride and sentimental feelings have in all old countries, and in Ireland more than any other I am aware of, added complications to its title, by imposing what may be called fanciful conditions on its tenure. I scarcely think it would be right to attempt to interfere with the owners in these matters. Even if it was otherwise inexpedient to extend to this country Lord Cairns's Act for the Sale and Transfer of Land, so much of its provisions might be adopted as would necessitate the registration in one office of all claims of land in Ireland of every description, and whether by the Crown or subject. The present state of things might be learned from a paper by Dr. Neilson Hancock, read before the Dublin Statistical Society. Another reform I would suggest would be a supplement to Lord St. Leonards' and Lord Cranworth's Acts for shortening deeds. Lord St. Leonards found in every well-drawn will and settlement common form clauses, for the protection of trustees, known to lawyers as the indemnity and reimbursement clauses; and he introduced and carried an Act through Parliament, to the effect that all deeds and wills should be construed as if they contained these clauses, unless their application was expressly negatived by the instrument. Lord Cranworth afterwards carried a similar Act; by which various powers are employed in mortgages, settlements, and wills, thereby greatly shortening their length. I then would suggest further legislation in this practical direction. At present, in an ordinary conveyance or assignment of land by way of sale or mortgage, there are inserted certain stereotyped covenants for title, which the purchaser or mortgagee

* 'The Method of Law,' chapters vi. and vii.

has a right to insist on without any express agreement on the subject. There is no reason, then, why their existence should not be implied in every such deed, leaving it open to the parties to make any agreement they please with respect to qualifying or extending their effect, or negativing their application altogether. This would shorten many deeds by at least one-third their length. And similar covenants against incumbrances by trustees might be implied, and, where only part of an estate is sold, covenants for the production of title deeds by the vendor. I shall now strive to go a little deeper to the root of the evil, by trying to show how the title to the land itself might, in my judgment, be simplified more than it is, without interfering unjustly with existing rights or restricting freedom of contract. The remedies I suggest are the abolition of the middleman tenure, and the assimilation of the law of succession in the different varieties of tenure. I propose that the middleman should be enabled to purchase, by compulsory sale, his landlord's rights, in analogy to the English Acts enabling copyholders to compel their lords of the manor to enfranchise their holdings. I do not think it would be any more violent interference with the landlord's rights to force him to sell them to the middleman, than it was to force a lord of the manor in England to enfranchise a copyhold.

It is scarcely possible that anyone will dispute the question that the assimilation of the law of succession, in freehold and chattel real property, would simplify titles, and therefore facilitate the transfer of land, as there are numerous instances in which the one farm, or even a portion of the same house, is held under both tenures, and even the one lease through one portion of its duration is freehold and another chattel. I cannot discover any valid reason why there should be the two kinds of tenure; nor were the two even deliberately or purposely created, but merely are remnants of the old feudal period, when leaseholds for years were not regarded as constituting any estate in land, and were allowed to go like cattle to the executor. The popular view is to assimilate the succession of freeholds to leaseholds. It would appear to me that a fair settlement of the question would be to recognise the eldest son's right to inheritance, to restrict the widow's right to dower, or one-third of the annual profits for her widowhood only, as exists in lands held in gavelkind, and to allot a third portion to the younger children during their minorities—leaving the remaining third to the heir, who would get the whole on his mother's death or second marriage, and on his brothers and sisters attaining full age. This, which would remedy the great hardship of the present law as regards freeholds, would, I think, make a useful alteration in the law of chattels real.

5. *On Impediments to the prompt carrying out of the principles conceded by Parliament on the Irish Land Question.* By W. Neilson Hancock, LL.D.*

In this paper I do not propose to deal with any principles as applied to the Irish Land Question, except those which have already been conceded by Parliament. With respect to one branch of the land question—the encouragement and facilities for the creation of peasant proprietors—a very elaborate inquiry has been made by Mr. Shaw Lefevre's committee, to ascertain the impediments to the successful working of what are called the Bright clauses. I propose to state the results of a scientific investigation on principles of economic science and jurisprudence of the impediments to the working of some of the other clauses of the Land Act. The British Government has to deal in India with the most eastern branch of the Aryan races, and in Ireland with the descendants of what was, before the discovery of America, the most western branch of the race. The reform of 1860, substituting contract for tenure in the relation of landlord and tenant, and the Act of 1870 recognising tenant right, reversing the presumption as to improvements and favouring small

* Published in 'Journal of the Statistical and Social Inquiry Society of Ireland,' pt. liv. vol. vii. p. 343.

ownerships—the legislation of 1877, giving a preference to equitable over legal rules, and favouring compensation and restraint in lieu of forfeiture, have effected such large changes, that the whole law as to land requires to be reviewed with a view to its simplification. The effect of the Land Act of 1870, in recognising tenant right, and the property of agricultural tenants in their improvements, has been to bring within the domain of law property worth some millions of money belonging to several hundreds of thousands of people, that before, owing to its want of recognition, required no legal machinery for its management and disposal. If this, as in every other case of concessions made by Parliament are to produce contentment, and lead to good government, they should be promptly and cordially accepted in all their consequences, and, above all, the legal and official arrangements should be as completely and as effectually as possible organised, so that the parties intended to be benefited may really get the benefit conferred on them by Parliament. Again, when English or Scotch institutions are extended to Ireland, the latest and most improved form which is adopted in either of the sister countries is the one that should be extended. The suggestions I have ventured to make all fall within these principles:—(1) That the eleven district registrars of the Court of Probate should be consolidated with the county officers, as under a recent reform the commissaries have been consolidated with sheriff's officers in Scotland. (2) That the office of sub-sheriff should, on the Scotch model, be made permanent, and consolidated with the county officers. (3) That the entire jurisdiction in bankruptcy should be entrusted either directly or by remission to the local courts as in Scotland. (4) That to enable poor people to prove their wills, and take out administration as cheaply and as locally as possible, the recent Scotch Acts for this purpose should be followed. (5) That taking the 150 towns in which County Court Judges sit, as the established convenient limit for exercise of local administrative jurisdiction, the petty sessions clerks of these towns should be the officers to carry out the cheap local proof of wills. (6) That to make the petty sessions clerks in these towns suitable for this and other duties that would devolve on them as subordinate officers of justice, the principle of the English Justices' Clerk's Act, 1877, should be extended to Ireland. (7) That the great principle of union rating carried for England in 1856, and extended in principle to the whole of London in 1867 and 1870, should be followed in Ireland: the commencement made in 1876 being completed by the full adoption of the English system. (8) That this reform would diminish the stimulus to interfere with the distribution of population produced by the 3,438 electoral divisions in Ireland, with an average population of 1,600, as compared with the 35,000 average population of the English area of charge. (9) That the English principle of valuation for taxation according to letting value should be substituted for the old Irish principle, still retained, of valuing according to scales of prices of agricultural produce. That the Irish principle conflicts with live and let live tenant-right. (10) That the adoption of a uniform basis of valuation for the purposes of taxation through the United Kingdom, besides its natural justice and equity, is of importance as a recognition as far as possible of the principle of maximum identical legislation. (11) That the principle of simplifying and codifying the law which in recent years has been so successfully carried out in India, should be applied to Irish law, and especially to the whole of the laws relating to land in Ireland.

SATURDAY, AUGUST 17, 1878.

The Section did not meet.

MONDAY, AUGUST 19, 1878.

The following Papers were read:—

1. *Report of Committee on Common Measure of Value in Direct Taxation.* See Reports, p. 220.

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2. *The Periodicity of Commercial Crises, and its Physical Explanation. By* Professor W. STANLEY JEVONS, *F.R.S.*

In this paper the author took up again the inquiry into the relation between the solar spot period and commercial phenomena, which he had previously treated, but, as he now believes, unsuccessfully, at the Bristol Meeting of the British Association (see Report for 1875, Transactions of Sections, p. 217). Observing that commercial collapses have occurred in 1866, 1857, 1847, 1837 (in United States), 1825, and 1815, the author adopts the opinion of Dr. Hyde Clarke and others, that such phenomena tend to recur in a period of about ten years.

He then points out that the series, although apparently broken (a crisis occurring in 1809–10, rather than in 1805, when there was no great increase of bankruptcy), may probably be traced back through the 18th century. There were great crises in the years 1793 and 1763, and very distinct ones also in 1772–3 and 1783. The principal part of the paper was occupied with an attempt to show that the great crisis of 1721, which followed the South Sea Bubble, falls into the series, as it was preceded by "stock jobbing" manias about the years 1701 & 1711, and was followed by one in 1732–33. There remains, in order to complete the whole series, two periods, 1742 and 1752, when there were certainly no great manias, or crises. But the author adduces evidence of a certain weight to show that in those years there were remarkable rises in the price of wool, and about 1752–53, there was a marked rise in the price of tin, which forms one of the best indications of commercial activity and good credit. He believes, then, that trade reached maxima of activity in or about the years 1701, 1711, 1721, 1732, 1742, 1753, 1763, 1772, 1783, 1793 (1805 ?), 1815, 1825, 1837, 1847, 1857, 1866. The intervals vary from 9 to 12 years; the average interval is 10·3 years. But, as the earlier dates, 1701 and 1711, are not well established, and the panic of 1866 was probably premature, as shown by comparison with the three preceding panics, the author prefers to compare the undoubted collapse of 1721 with that of 1857, giving a mean interval of 10·46 years. If we take the year 1763, which was also a year of well marked crisis, and compare it with 1857, we obtain 10·444. The mean length of the commercial period is thus almost identical with Mr. J. A. Broun's estimate of the sunspot period, namely, 10·45 years, which again is almost exactly the same as Lamont's earlier estimate.

The author infers that the phenomena are probably connected; but, as he and other inquirers have failed in discovering a like cycle in the price of corn, he believes that the connection must be sought rather in the varying produce of the crops in the tropical or other countries, where the meteorological influence of the solar period has already been detected. In corroboration of this opinion he points out that the exports of goods from England to India, when graphically represented, display a certain appearance of decennial variation, especially in the earlier part of the 18th century.

In conclusion he alludes to the contemporary state of trade, quoting a statement

of the numbers of bankruptcies in England and the United States, to show that the latest crisis must be assigned either to 1877, or, it may be, to 1878. In either case the theory of decennial variation will be verified as closely as can be expected.

3. *The Definitions of Political Economy. By* Professor MAGUIRE.

4. *Some Statistical Researches into the Poor Removal Question, with special reference to the Removal of Persons of Irish Birth from Scotland. By* W. NEILSON HANCOCK, *LL.D.**

There were 774,310 persons of Irish birth in Great Britain in 1871, of whom no less than 682,000 were of twenty years of age and upwards. As there were only 2,900,000 persons of Irish birth of twenty years of age and upwards in Ireland, those in Great Britain are about one-fifth of the whole—without counting migratory labourers. The number in Scotland of this age. 184,000, is one-tenth of the whole population of that age in Scotland, 1,788,000; while the number in London, 82,900, is only a twentieth of the corresponding figure, 1,789,000. Dr. Alison, in a paper read at the British Association in Belfast in 1852, ascribed mortality of persons of Irish birth in Scotland in part to operation of Scotch poor-law. Dr. Lyon Playfair noticed unhealthiness of persons of Irish birth in Scotland. Amongst the defects in Scotch poor-law noticed by Dr. Alison were the period of residence to protect against removal, still five years, though reduced to one year in England in 1865. The defects in the law as to acquiring and losing a settlement, noticed by Dr. Alison, were remedied in England in 1876, but not yet in Scotland. Scotch poor law is in advance of English in allowing questions of chargeability to be adjusted between different localities in Scotland, without a removal, and so contains germs of total abolition of removal. In conclusion, I would repeat what I said on this question some seven years ago, in a paper before the Statistical Society of Ireland,—The prestige of our legislation would be strengthened, if we were able to have laws, like those relating to poor removals that affect the labouring classes in the whole three kingdoms, assimilated and reduced to an enlightened and beneficent code, by collecting what is best out of each of our laws in England, Scotland, and Ireland. A large cause of discontent would be removed if we were able to say to the migratory labourers of these kingdoms—"No matter what is your race or place of birth—no matter where you labour—your relations to the State in any calamity that overtakes you will be the same at Belfast, at Glasgow, and at Liverpool—in Dublin, in Edinburgh, and in London."

5. *On the Education and Training of the Insane. By* JOSEPH LALOR, *M.D., Resident Medical Superintendent, Richmond District Lunatic Asylum, Dublin.*

I propose to consider in this paper some of the general principles on which the education and training of the insane can be dealt with most advantageously; starting with the proposition that education and training form the basis of the moral treatment of all classes of the insane. Commencing with criminal lunatics, I adopt the division of criminal lunatics into two classes proposed by Dr. Orange, of the Broadmoor Asylum:—(1) Those whose offences have been the direct result of their insane state, and who up to the time of the outbreak of insanity have in many cases led honest and industrious lives; and (2) those who have been certified to be insane whilst undergoing penal servitude in convict prisons, and who consist chiefly of habitual criminals whose offences against law and order are part of their every-day life, their habitual actions being anti-social. The first class may, I think,

* Published in 'Journal of the Statistical and Social Inquiry Society of Ireland,' pt. liv. vol. vii. p. 356.

be very properly treated in district lunatic asylums, and not dealt with as a distinct class. As regards the second class, there are unquestionably great disadvantages in mixing them with the general inmates of a lunatic asylum. But systematic and skilled education and training are obviously called for in the case of all the patients in lunatic asylums, all of whom are prone to breaches of the moral laws. In the district lunatic asylums of Ireland the great insufficiency of the means of educating and training are obvious.

The Charity Organisation Society of London, after very prolonged inquiry, conducted with peculiar advantages for obtaining information, have come to the conclusion that voluntary charity has not proved equal to providing a remedial machinery for the training of imbeciles and idiots coextensive with the evil, and that such provision cannot be made without the intervention of the State. The society recommends that the administration of such provision should be conducted by governing bodies composed of representatives of the local magistrates, representatives of the guardians, and persons appointed by the Crown, and that its cost should be met partly out of local rates and partly out of the public revenue. I think municipal bodies should be represented on the governing boards; and whilst I concur in the other views above set forth by the Charity Organisation Society, I dissent entirely from an opinion which they have expressed, that idiots and imbeciles should be treated distinctively from other classes, and that they ought not to be associated with lunatics in asylums. Indeed, I would disapprove of the introduction of any system that would make provision for the care and training of idiots and imbeciles of the poorer classes distinct in the organisation of its administration and mode of support from that for the insane afflicted with other forms of insanity.

It is much to be wished that some system may be devised by which the due care and treatment of the insane poor, labouring under the different forms of insanity, may be dealt with so that they should be recognised in law as belonging to one abnormal family or group; and that their interests, as well as those of the public at large, should obtain that increased and much-needed advancement which might be expected from the combination of existing diverse systems into one consistent and homogeneous whole, working with the full power which such union would confer.

Assuming that educational training is a powerful, improving, and ameliorating agent with all classes of the insane, it is important to bear in mind that it does not produce its full results, in many cases, until after the lapse of a very long period; and it has led, in the Richmond Asylum, in my experience, to most unexpected improvement, and even cure, only after its continuance for years. Hence I venture most earnestly to deprecate any such interference, by legislative enactment or otherwise, as would make its trial short and insufficient.

In the year 1857, on my appointment to the Richmond Asylum, I found with much pleasure that a schoolmistress was a member of the staff, having been appointed in 1854. At the time of my appointment she had a class of about twelve patients, and also gave elementary instruction to such of the nurses as required and wished for it. I have endeavoured to develop, extend, and strengthen systematic education and training as part of the moral treatment of all forms of insanity in this asylum, and I trust my efforts have been attended with some success.

In reference to the education or training of the insane, no matter of what class or age, I wish to state that I try to have the patients engaged in the same pursuit for not more than from one to one hour and a half consecutively. Monotony, whether of work, education, or recreation, appears to me to be injurious to the insane of all classes and ages. I consider the alternation of literary, æsthetical, moral, and physical education, with industrial employment and recreation (so as to produce variety of occupation), to be of great advantage in the treatment of the insane, whether the particular form of the insanity be mania, melancholia, monomania, dementia, idiocy, or imbecility.

The great want of further and better provision for the cure of recent and curable cases, and for the training of idiots and imbeciles in Ireland, has, for several years, received some attention, and the latter subject has been brought into

still more prominent notice by the investigations and reports of the Charity Organisation Society of London. The most approved system of training juvenile idiots and imbeciles is founded, as appears to me, on the same general principles, and includes nearly the same details, as those on which the educational system in the Richmond has been founded and carried out, until it has reached its present development.

By comparatively cheap structural changes, and the removal of a large number of quiet and incurable cases at present in district asylums in Ireland, who might be cared for sufficiently well in one or more workhouses selected and appropriated to such a purpose, and at less cost than in the present district asylums, I believe that accommodation might be made for some hundreds of juvenile idiots and imbeciles, and means presented for their receiving that education and training of which they are admittedly in urgent want.

In the district lunatic asylums of Ireland the number of single rooms is, I believe, much larger than is called for by what I consider to be the most advanced opinions on the use of seclusion. In some of the best managed asylums of England seclusion is very rare, and my own experience leads me to use it very sparingly. In fact, a very large proportion of the single rooms in the Richmond Asylum are occupied by the quietest patients in the house, with the view of putting into associated dormitories the class of patients often called refractory, for whom single rooms were formerly considered necessary. In my opinion, single rooms would not be wanted in a larger proportion than one for every twenty patients. From the thirty-fourth table of the Inspector's Report for 1872, which is the last return giving the number of associated and single rooms in the district lunatic asylums of Ireland, there appears to have been at that time about one single room on the average for every four patients, making about 2000 single rooms in institutions with a total number of patients amounting to 8000. The space occupied by single rooms and the connecting corridor, if converted into large rooms, would accommodate two for every one accommodated according to present construction, and a gain of 1600 beds would thus be available for the accommodation of large classes of the insane at present in much need of suitable provision for their proper care and treatment. I am confident that the means of treating the patients in a way more conducive to their comfort and improvement would thus be obtained at a cost which I would estimate not to exceed 20*l.* per head, or about one-fourth of what it would cost to build new asylums. The removal of quiet and incurable cases, and the conversion of single rooms and corridors into large rooms, would in this asylum alone give means for the education and training of several hundreds of the insane who at present are deprived of such an opportunity. The present staff would, without increase of numbers or of expense, be sufficient, and the advantages thus offered on the score of experience and economy of time and money are obvious.

Preconceptions founded on insufficient data would, I think, be removed by an impartial examination of the system carried out in the Richmond Asylum, and it will always give me great pleasure to afford persons anxious to judge it by personal observation the opportunity of doing so; but I would suggest that such persons should visit during our school hours, viz. :—From nine to one o'clock, from April 1 to October 1, and ten to two o'clock from October 1 to April 1 (vacations at Christmas, Easter, and Midsummer excepted).

Summarising what I consider some very important items of our system here, I note that out of 479 male patients in the house on May 17, 400 were employed either at school or industrially, or both combined, and only 79 were wholly unemployed; 45 of the unemployed were so in consequence of being under medical treatment, leaving only 34 men unemployed purely owing to their state of mind. Of 553 female patients in the house on the same day, 448 were employed either at school or industrially, or both combined, and 105 were wholly unemployed; 89 of the unemployed were so in consequence of being under medical treatment, leaving only 50 unemployed purely from the state of their mind. In the management of the insane, it is of the first importance to keep them from mischief and harm: and with them, as with the sane, there is no means of doing this so reliable or so good as healthful employment of mind and body. Morning and evening prayers

are said in all the divisions of the Richmond Asylum, the Protestants and Roman Catholics being in separate rooms, and in care of an attendant of their own religious belief (being a school attendant, when possible). The average number attending morning and evening prayers is 322 males and 486 females, making 808 of both sexes.

In reference to the employment or occupation of the insane in this asylum, I consider that one of the advantages of the school system is, that it provides an occupation for some, and leads to the occupation of others who would otherwise be wholly unoccupied. In reference to industrial employment, I wish to observe that I try to provide such as is most suited to the tastes or antecedents of the patients, and at the same time such as, with certain limitations, is most useful to the institution.

The total disuse of restraint, and the very infrequent use of seclusion—the freedom allowed to all our patients to exercise and have various sorts of games on the open grounds, in place of enclosed yards—are very gratifying features. The number and cost of our staff, estimated per head on the daily average number of patients, is less in this than in the other district lunatic asylums of Ireland; and this fact, taken in connection with our large teaching and training power, shows that education and industrial employment carried out, as they are here, systematically, by skilled hands, do not necessarily increase expense. The cost per head for salaries and wages here, estimated on the average number in the house, was for 1876 4*l.* 0*s.* 5*d.*, compared with 4*l.* 19*s.* 6*d.*, the average cost per head of the staff in all the other district lunatic asylums in Ireland in the same year. Our staff of officers and servants was at the rate of one for every 8·8 patients—the staff of all other district asylums in Ireland was one to every 6·6 patients.

In the number of the *Journal of Mental Science* for October 1860 I published a paper in which I advocated large in preference to small asylums, and any person desirous of doing so can there see the reasons on which I grounded my preference. The experience which I have since had in the education and training of lunatics makes me still more in favour of large asylums than I was in 1860, particularly in view of this question of education; and as the same general principles and machinery are applicable in their case, so far as training is concerned, as in that of idiots and imbeciles, it may be presumed that if the result of experience and reasoning has led to a decided preference for large over small training institutions, in the case of the latter, it should favour a similar preference in the case of the former. The Earlswood Asylum, which had 184 idiots and imbeciles in training in 1857, and 599 in 1877, appears to have advanced in efficiency and public estimation as it has enlarged in size. The Charity Organisation Society and the Metropolitan Asylum Board appear to think 500 a favourable size for a training school for imbecile children. The Charity Organisation Society also states that:—"Training schools and adult asylums, however they may differ in their internal arrangements, have mutual relations which often make it desirable that they should be in each other's neighbourhood, and under the same general superintendence." I coincide in this opinion, and I think it is from a wise forethought that a site has been selected at Darenth, sufficiently large for an asylum for adults, in addition to the training school for 500 children now near completion. It is probable that such an asylum, with accommodation for 2000 adults, will be built at Darenth, and ample evidence is thus afforded that extended experience and consideration is found to favour large and combined in preference to small and distinct asylums.

Ever since physical repression and fear have ceased to be the principles relied on for maintaining even tolerable security, order, and quiet, and promoting recovery or improvement amongst the insane in confinement, medical and moral treatment have been brought more and more into requisition. Moral treatment is only another name for education and training. But the great defect in carrying out the recognised principles of moral treatment has been that the agents employed have not been sufficiently adapted to the object in view. It is absurd to expect that moral treatment can be efficiently carried out by a few resident medical and other officers, however intelligent and well-intentioned, through their direct and personal exertions, which are necessarily desultory. There must be an organisation in con-

nection with the object, analogous to that which is found essential for the education and training of the sane. In the case of the insane, it is further obviously desirable that the educational agency, which has been found so efficacious in school hours, should not wholly cease after school hours are over. It would be contrary to sound principles to remit the moral treatment of the insane after school hours to the sole charge of attendants not prepared by their antecedents for the discharge of such a duty. Everyone with extended practical experience of the subject knows that a very large proportion of the attendants in lunatic asylums have not received that instruction calculated to make them skilled agents in fulfilling the requirements called for in the moral treatment of the insane.

In each division there should be at least one such attendant, whilst at present I fear that there are many asylums without even one such attendant in the whole asylum. To carry out individual moral training in asylums, even of small size, appears impossible, even if it were desirable. Direct individual training is too likely to degenerate into argumentation, not calculated to influence an insane person beneficially. The problem to be solved is to break the habit of abnormal feeling and acting as much as possible, and this can be better done by indirect and class training than by direct individual training. In classes, the influence of the example of the large mass of the quiet and orderly on their more disorderly inmates multiplies the good result.

In instructing sane adult classes, whether in morality, in science, or in literature, the advantage of teaching in class becomes every day more fully appreciated and established. Singing, music, and amusements for the million are every day more called for by the public voice, and the opinion is, I believe, gaining ground that religious instruction carries more influence when addressed to large than to small congregations. What reason is there for supposing that the powerful mental and moral lever of example should not be applied on the same principles to the insane as to the sane mind? Be this as it may, I think it will be admitted that any influence which is good should be as continuous as possible. To keep the mind free from insane or immoral impressions is an obvious desideratum. This result is to be sedulously sought for; and even in a negative form it opens the door for the introduction of normal thought. Normal action follows normal thought. To keep the insane from mischief, to themselves or others, is a chief reason for placing them in asylums, and I know of nothing more conducive to this end than healthful occupation of mind and body; and such occupation can only be efficiently conducted by trained and skilled hands.

It is generally admitted at the present day that, to be qualified to teach, literary knowledge alone is not sufficient, but that the teacher should also be trained to teach; and I believe that the same principle should be kept in view in selecting those who are to educate and train the insane, whether in or out of school. Those who have been trained as monitors and monitresses in normal schools and public establishments are a class from whom persons well fitted to act as attendants may be obtained, who, with a little additional special instruction, would become admirably suited to carry out the moral training of the insane in asylums, whether in school-classes or otherwise. In Ireland there are a number of such persons suited and willing to take the situation of attendants on the insane in asylums, moderate as is the remuneration attached thereto. Their education—the habits and skill in teaching and influencing to good ends which they have acquired, the knowledge of singing and music and of directing industrial occupations, whether for males or females, which they often possess, present obvious advantages; and it is much to be regretted that many of this class (if I am rightly informed) take situations in their own country lower in value and position than that of an asylum attendant, or emigrate to our colonies or other countries. It is from this class that I have selected what are called school attendants in the Richmond Asylum; and my experience of them gives me no room for hesitation or doubt in recommending the example of this asylum in this respect for general imitation. The want of school-rooms is a difficulty sometimes alleged as standing in the way of establishing schools in asylums. But school-rooms are not necessary, and we have none here. Schools are alleged by some, who admit their practicability and value in the Richmond

Asylum, to be impracticable in most other asylums, particularly where the patients are of a rude, illiterate, and agricultural class. But it is to be borne in mind that the education and training of the insane is chiefly of use, not for the literary and industrial knowledge imparted, but as supplying the best means of restoring the mind to a healthy state, of teaching habits of good order and self-control, and of relieving the tedium of idleness, and so promoting contentment and even happiness. The ignorant, as well as the educated, present subjects capable of deriving benefit from that moral treatment which skilled education and training alone can adequately supply. Amongst the causes which lead to insanity as well as to crime, I believe ignorance to be one; and it should be noted that out of 8183 patients in the district lunatic asylums of Ireland, only 1899 are set down as well educated and capable of reading and writing well, whilst there are 5516 who can only read and write indifferently, read only, or neither read nor write. Whilst the insane in lunatic asylums are in general so deficient in education, it is noteworthy that 125 were students or teachers before they became insane. Here is a body amongst whom several are by no means incapacitated from teaching by their mental condition. In this asylum, out of fifteen of this class, several give valuable aid in carrying out our school system. Twelve patients who were learning to read and write in this asylum in 1837 were taught, I should suppose, by a fellow-patient, as there was then no paid teacher in the asylum; and in 1852 a few of the female patients in this asylum received school instruction for some time under the direction of one of the patients, who had been a schoolmistress, and the result was satisfactory. The circumstances in the public asylums in England and Scotland are, I believe, at least equally favourable to the introduction of education and training of the insane of all classes as they are in Ireland; and the advantages would, I feel confident, be equally great.

TUESDAY, AUGUST 20, 1878.

The following Papers were read:—

1. *Some Remarks on the Desirability of Simultaneous and Identical Legislation for England and Ireland.** *By* H. L. JEPHSON.

The Act of Union is very far from being complete. First of all, though it declared Her Majesty's subjects of Great Britain and Ireland to be on the same footing generally in respect of trade and navigation, it left both countries with separate customs department and tariffs, and thus left them in this matter virtually separate countries. Next, it left each country with its separate exchequer, its different coinage. Next, it directed that all laws then in force, and all the courts of civil and ecclesiastical jurisdiction within the respective kingdoms, should remain as then by law established within the same, subject, however, to "such alterations and regulations from time to time as circumstances might appear to the Parliament of the United Kingdom to require." It left Ireland also with a separate peerage, a separate Privy Council, and finally, and perhaps the most important of all, as being the ever fruitful cause of separate legislation—it left Ireland with a separate Executive. Seventeen years elapsed before any material progress was made, the union of the exchequers then had taken place. The next step of importance was not taken until 1825, when the two countries were commercially united, and in the following year the currencies were assimilated; but it was not until so very recently as 1858 (just twenty years ago) that the fiscal systems of the two countries were finally assimilated. The very striking fact, however, remains that after a lapse of now very close on 80 years, many of the defects of the Act of Union exist in full vigour. About the close of the first quarter of the century a system of legislation crept in, and gradually gained ground, which resulted in the creation of a vast number of differences. Reforms in the administration of justice naturally became necessary, but instead of their being carried simultaneously for both countries, as ought to have been done, each country was dealt with separately. It might reasonably be expected that in the matter of sanitary legislation the two countries should be treated as one. Such an opinion, however, if it prevailed, was not acted on. In 1855 a Sanitary Act was passed for England only. In 1866 when an invasion of cholera was anticipated in Ireland, the only precautions which the Irish Privy Council could take against the introduction of that disease into Ireland were under the condemned Acts of 1848 and 1849 which were still in force there. The emergency, however, became so great that the Sanitary Act had to be passed for Ireland, and the law was then assimilated to the English law. Another difference created since the Union, and one which entailed a number of others, was as regards the valuation of property. In England and Scotland the valuation of property was based upon rent; in Ireland it was based on the prices of agricultural produce. Furthermore, in Great Britain the valuation is annually revised, whereas in Ireland no revision as to the value of land as distinct from buildings had taken place during the last 25 years. The result was that the valuation of property in Great Britain and Ireland was far from being approximate. Besides those which the author had alluded to, there were differences in the laws relating to the representation of minorities, relating to the legal status of women, in the pawnbroking laws, in the

* The paper has been published *in extenso* by William McGee, Nassau Street, Dublin.

licensing laws, in the poor laws, and in a host of other minor subjects. The principle which should regulate all legislation for Ireland might be thus stated: Firstly,—In all legislation regarding matters which affect equally the people of both countries no differences whatever should be permitted. In the next place where similar results could not be obtained by identical means, the difference of means should be as far as possible minimised; and the absolute condition should be insisted on that legislation should be simultaneous. And lastly, where special legislation was a necessity, it should aim at bringing the matters that formed the subject of such legislation as far as possible into harmony in the two countries. The rules which should be followed to give effect to these principles might be thus stated:—No measure that came under the first of these principles should be introduced into either House of Parliament for England only, but should be made to extend to both countries. When special clauses were required to adapt a measure to the institutions of Ireland, the necessary clauses, instead of being postponed to a future period, and then made a separate Act, as now so often happens, should be tacked on to the principal Act. The Ballot Act showed how, even in a large and very complicated subject, simultaneous legislation was possible. Certain cases remained where the subject would be of such a nature or extent that a separate Act for Ireland would be required. Under this class would come all the legislation which would have to be effected to assimilate Irish to English institutions, and to bring Irish laws into harmony with English laws. In these cases the English precedent should be followed as closely as possible, and every unnecessary difference avoided. If the principles here stated were kept steadily in view and systematically acted on, a considerably increased degree of legislative uniformity would soon be attained; and what was also very important, a guarantee would be afforded that such uniformity would be lasting.

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2 *On the Importance of raising Ireland to the Level of England and Scotland in the matter of Industrial Schools and Compulsory Education. By* W. NEILSON HANCOCK, *LL.D.**

The official statistics of children committed to reformatories in Ireland show that only 10 per cent. of the boys and none of the girls were properly educated. More than half the girls and three-fifths of the boys were totally ignorant. To remedy the state of ignorance disclosed, the following suggestions as to industrial schools were recommended for adoption:—The suggestions of the Recorder of Dublin (Mr. Falkiner) that Lord Sandon's clause in the Act of 1876, for establishing day industrial schools, should be extended to Ireland. The suggestion of Mr. Lentaigne, Inspector of Reformatory Schools, that the full benefit of English law as to industrial boarding schools should be extended to Ireland. As to compulsory education, it is proposed to follow the Scotch Act of 1872, only substituting in the details Irish existing centralized official machinery for the Scotch local machinery. Elementary education of children between five and thirteen to be obligatory on parents. Guardians to be enabled, in case of poverty, to pay school fees. Irish police to collect information as to neglect of parents, as officers of local boards do in Scotland, and to prosecute—unless medical officer, as to health, clergyman, as to family reasons, or inspector ot National schools, as to want of school accommodation, certified that parent might be excused. Where National School inspector reported school accommodation deficient, or justices refused to convict for that reason, reports to be referred to Commissioners of Donations and Bequests, to see if any unused endowments were applicable, and the inspector of industrial schools to see if want could be met by industrial day schools and other voluntary effort. From such reports could be collected, as to whether assistance for industrial and primary education would be necessary, like that afforded to intermediate education by the Irish Intermediate Education Act of 1878.

* Published in 'Journal of the Statistical and Social Inquiry Society of Ireland,' part liv., vol. vii., p 348.

3. *On some Economic Fallacies of Trades Unionists.*
By Professor J. J. SHAW.

The theory of the Unions on the subject of wages was that they might be raised without either increasing capital or diminishing the supply of labour by lowering the rate of profits, and, on the other hand, they might be lowered without either diminishing capital or increasing the supply of labour by raising the rate of profits; that the most obvious way to increase the reward of the labourer was to diminish that of the capitalist, and the direct way to diminish the labourer's reward was to increase the share that fell to the capitalist. This reasoning overlooked the fact that there was in every community a certain rate of profit which was the minimum that any capitalist would be content to accept: that if his profits were permanently forced below that minimum he would withdraw his capital, and in the end there would result a fall of wages even below the point at which they stood when the artificial rise commenced. The idea entertained by the organisers of trades unions of effecting by their action a permanent rise in the average rate of wages, independently of any change in the general productiveness of industry, was one that could never be realised. This could be done only by lowering the rate of profit, and in these countries the rate of profit was always on the verge of the minimum. To lower the rate of profit, therefore, was to check accumulation, and thereby to diminish the fund out of which labour was paid. Labourers, by combination, could do much to alter the rate of wages temporarily, and in particular trades. But it was evident that the high wages were obtained at the expense of the consumers, and if the commodities they produced was one consumed by their own class they reduced the wages of their fellow-workmen as much as they raised their own. To the important economic question whether the wage-earning classes could by combination permanently raise the average rate of wages, he was obliged to answer "No." What the working classes most of all needed to be taught was that their destiny was in their own hands, that their happiness was not made or marred by the by-laws of their unions or the tyranny of their masters, but depended wholly and solely on their own prudence, foresight, and self-control.

WEDNESDAY, AUGUST 21, 1878.

The following Papers were read:—

1. *On the Social Aspects of Trades Unionism. By* J. H. M. CAMPBELL.

The Trades Unions are advantageous to the working classes, as benefit and insurance societies, and centres of combined legitimate action. It is, moreover, to the persistent agitation of these unions, aided by the efforts of philanthropists, that are to be ascribed the many legislative enactments of modern times against the employment of women or children in unhealthy or too-protracted labour, against the use of defective and dangerous machinery, and affording facilities for the erection of comfortable and well-aired dwellings. But Trades' Unions assumed a very different aspect when examined with regard to that which is avowed to be their primary object, and to which all others are ancillary and subservient, that of controlling the labour market, and regulating the amount of their wages. The author then reviewed the economic conditions regulating the rise and fall of wages, with which he contended Trades Unions could not attempt to interfere without injury to their members and the country. Respecting strikes, nothing could be more suicidal than the policy sometimes pursued of going out on strike to avoid a reduction of wages in times of depressed trade. The year 1877 affords a striking illustration of the truth of this statement, for, while the country was suffering from acute commercial depression, I find that in that year no less than 191 strikes occurred, the majority of which were intended, not to secure a rise of wages, but to prevent the reduction rendered inevitable by the state of trade, and were consequently disastrous failures. Little less injurious was the consequence of a strike, nor the plan at present in favour with the working classes for retrieving their position under the prevalent depression by shortened hours of labour. Every reduction in the hours of labour, unless compensated for by superior efficiency, is equivalent in its effect to a rise of wages, and, consequently must either raise prices or lower profits. The effect of the latter result we have already seen, while increased prices arising from such a cause would drive out the English manufacturer, and enable foreign competitors to undersell him in all those industries in which the advantage possessed by England is trifling in extent. The most disastrous and fallacious form which this claim for shortened hours of labour assumes is when it is urged as a means of bringing in unemployed workmen. Why, it is asked, should not the workmen limit the supply of their labour by working less hours, and thereby give others a chance of sharing in the amount of work, and consequently in the wages offered by employers? To this, as to all those regulations of trades unions which, like their restrictions on apprenticeship, are for the avowed object of making work, the simple answer is, that it is never work that is deficient, but capital to give employment, and that the greater the total produce is the greater will be the amount saved and devoted to the subsequent employment of labour: so that it would seem to be a self-evident proposition that if workmen combine to do only half the amount of work they are capable of performing, there will be only half the amount of wealth in the country that it is possible there should be, and, consequently, only half the amount to devote to the purchase of fresh labour.

2. *On Adam Smith's Theory of Rent.* *By* W. D. Henderson.

I purpose confining my paper to one aspect of the subject, viz., the effect of the payment of rent upon the productiveness of the ground, and this, it will be seen, includes at least one aspect of the great question—is it for the benefit of the community that land should be owned by persons who let it out for cultivation rather than by the cultivators themselves? Again, my investigation will not answer the question—would it be worth while to destroy the present system upon which land is owned, and substitute for it some form of ownership by peasant proprietors? It was the well-known opinion of Smith that land which would grow almost anything would afford a rent. His reason for this opinion was, that agriculture was more profitable than any other mode of employing capital. The question may fairly be asked, why should not the same rule be applied to agricultural rents as Smith applies to rents of mines, and why should not the landlords refuse to let lands which would yield them no rent, either on account of the natural barrenness of soil or the expense of working it? Now, the reply given by modern political economists is this. They admit that in fact there are large tracts of land which would be cultivated by peasant proprietors, but which will not be cultivated by mere tenants. So far we are all agreed, and this admission furnishes a perfectly solid economic basis for the demand of which we often hear in Ireland, that the waste lands should be dealt with by the State. I shall endeavour to point out what are the landlords' motives to prevent the increased cultivation of the soil, and what are the means taken to attain his end, it being assumed that his only motive is to obtain the largest possible rent for himself. His first motive will be to keep down the poor rates. He has constantly before his eyes the risk of the labourers and their families coming on the poor rates in bad seasons, or through sickness or ill health. The burden of supporting them properly falls on the land; and it is a source of incessant watchfulness on the part of the landlord that it should not be in any way excessive. So strong has this motive been found in practice that it has been necessary in England to extend the area of rating for the poor rates. His second motive is his desire to have a steady and certain income. He is, in fact, like other men in his position, disposed to take the world very easily indeed; he prefers large farms to small. He would rather deal with one man of capital than with a dozen men who might, and probably would at times give him trouble. From this, again, arises another important result. The landlord is most anxious that he should be absolute owner of his land, and this for various reasons, political, social, and economic. And all these motives combine to dictate his conduct as to having large farms. Now, a system of small farms, such as we have in Ulster, almost necessitates that the tenants shall make the improvements, both permanent and otherwise. The desire also of the landlord to get an addition to his income in the shape of an increased rent will tend in the same direction. He does not care to be met with the argument that so many labourers have been employed. Such seem to be the chief determining motives of the landlords. The mode in which they attain their ends are very simple. In the first place the landlords absolutely refuse to allow of the sub-division of farms. No matter how large may have been the farmer's holding, or what his tenure, the landlord reserves the power, and exercises it, of compelling the farmers to cultivate it themselves, and he forbids after their death any sub-division of their interest. The peasant proprietor, or the semi-peasant proprietor, who would sub-divide within reasonable limits, and cultivate carefully, has no chance on the estate. Not merely does he prevent sub-division, but he is disposed to pursue a system of consolidation of farms.

Section G.—MECHANICAL SCIENCE.

President of the Section—Edward Easton, Esq., C.E.

THURSDAY, AUGUST 15, 1878.

Mr. Easton gave the following Address:—

At the commencement of each Annual Report it is stated that one of the objects of the British Association is "to give a stronger impulse and a more systematic direction to scientific inquiry," and its division into Sections was made with the view of concentrating such inquiry upon the several departments of Science.

I propose to endeavour to further that object by making the Address, which I have the honour to deliver as President of Section G, a preface as it were to the fuller consideration of a subject of the highest interest to all the inhabitants of the United Kingdom, and not least to those who have so freely extended their hospitality to us on this occasion. That subject is the Conservancy of Rivers and Streams in the widest sense of the term.

It is worthy of remark that it was on the occasion of the first visit of the British Association to this city in the year 1835, that the Mechanical Section was virtually instituted. Previous to that meeting the Section of Mathematics and Physics had undertaken the discussion of questions having reference to the practical application of physical science, but at the Dublin meeting a subsection was specially appointed, which in 1836 became Section G. The late Mr. George Rennie, that distinguished son of one of our greatest engineers, presided on the occasion. His report on Hydraulics presented to the Association in 1834 is full of research, and should be studied by every one interested in the question of rivers.

I am glad to be able to announce that my Address will be followed by a series of Papers on the same subject, the authors of which are certainly very well qualified to elucidate its details; and I trust that many of the other eminent men who are attending this meeting of the British Association will join in the discussion of these Papers.

By the Conservancy of Rivers and Streams I mean the treatment and regulation of all the water that falls on these islands from its first arrival in the shape of rain and dew to its final disappearance in the ocean.

I had at first, in my ignorance, contemplated treating the subject in a still wider manner by referring to the rivers and streams of other countries; but I soon found that the vast extent of the field to be traversed would make it extremely unlikely that I could, with any satisfactory result, attempt the more restricted task which I have now before me. Indeed, without the promised aid which I have referred to, I should have shrunk from attempting it at all.

The question of the Conservancy of Rivers and Streams involves the consideration of their regulation for the following principal purposes:—

1st. For the supply of pure and wholesome water for the domestic and sanitary wants of the population.

2nd. For the supply of water of proper quality and sufficient quantity for industrial purposes.

3rd. For the proper development of water power.
4th. For the drainage and irrigation of land.
5th. For navigation and commerce.
6th. For the preservation of fish.

In the early days of the world's history there were attempts to regulate and control the waters of rivers—some of them devoted to military and dynastic objects, but the majority to generally useful ends. Herodotus, speaking of Semiramis, who lived some 2000 years B.C., tells us that she raised certain embankments, well worthy of inspection, in the plain near Babylon to control the river Euphrates, which till then used to overflow and flood the whole country round about. He also mentions a lady, who lived at a still earlier period, who altered the course of the same river, as a defence against the Medes, to such an extent that, "whereas the river Euphrates ran formerly with a straight course to Babylon, Nitocris, by certain excavations which she made at some distance up the stream, rendered it so winding that it comes three several times within sight of the same village" (Ardericca, in Assyria). "She also made an embankment along each side of the Euphrates wonderful both for breadth and height, and dug a basin for a lake a great way above Babylon, close alongside of the stream, which basin was sunk everywhere to the point at which they came to water, and was of such breadth that its whole circuit measured 420 stadia (more than 50 miles). The soil dug out of this basin was used in the embankments along the water side. When the excavation was finished she had stones brought, and bordered with them the entire margin of the reservoir. These two things were done—the river made to wind, and the lake excavated—that the stream might be slacker by reason of the number of curves and the voyage rendered circuitous, and that at the end of the journey it might be necessary to skirt the lake, and so make a long round. All these works were on the side of Babylon where the passes lay, and the roads into Media were the straightest; and the aim of Nitocris in making them was to prevent the Medes from holding intercourse with the Babylonians, and so to keep them in ignorance of her affairs." The same energetic princess made brick embankments and quays, and a bridge over the Euphrates, and to do this she turned the entire stream of the river into an artificial cutting, the natural channel being left temporarily dry until the bridge was finished, when the Euphrates was allowed to flow into its ancient bed. It was into this very cutting that Cyrus directed the course of the Euphrates when he took Babylon, 538 B.C. In the time of Herodotus himself, about B.C. 450, there were embankments to the river at Babylon; for he says, "The city wall is brought down on both sides to the edge of the stream; thence from the corners of the wall there is carried along each bank of the river a fence of burnt bricks, with low brazen gates opening on the water."

The same historian, in his second book, describes the hydraulic works of the first king of Egypt, Men or Menes, which were not only gigantic in themselves, but productive of the most important results to the inhabitants of his kingdom. "Before his time," Herodotus says, "the river flowed entirely along the sandy range of hills which skirt Egypt on the west side. He, however, by banking up the river at the bend which it forms about 100 furlongs south of Memphis, laid the ancient channel dry, and dug a new course for the stream halfway between the two lines of hills."

Passing to Greece, perhaps the most wonderful instance of the successful regulation of water is to be found in the subterranean channels (the modern Greek Katabathra), by which the waters of the river Cephisus are carried through Lake Topolias (the ancient Copais) into the sea. These tunnels, which are partly natural and partly artificial, have always served to prevent the lake overflowing the adjoining country.

The well-known tunnel, or emissarium, from the Alban Lake is an example of Roman work. This tunnel, of a man's height, and cut through 6,000 feet of lava, is said to have been begun in obedience to the Delphic oracle in the sixth year of the siege of Veii, B.C. 398. By it, the overflow of the lake which used periodically to flood the Campagna was prevented, and the waters were conducted through it in an even flow for the irrigation of the fields which it had formerly laid waste.

Three vertical shafts and one made in an oblique direction still remain; the marks on the hard rock show that the chisels employed in the cutting were an inch in width. Another Roman work of still greater importance was the emissarium at Lake Fucinus, planned by Julius Cæsar and carried into execution by Claudius. This was a tunnel three miles in length, extending from the lake to the river Liris (the modern Garigliano), one mile of it being driven through a mountain of cornelian rising 3,000 feet above the lake. It employed 30,000 men for eleven years. There are many perpendicular shafts for raising the rock to the surface and lateral galleries for disposing of the spoil, so as to enable this large number of men to work without interfering with each other.

The supply of water to different cities of the ancients has been the motive for the execution of the most stupendous works, which are almost numberless. It will be sufficient for me to allude to the works constructed for the supply of the city of Samos, about the time of Polycrates, B.C. 530, in which case a tunnel was driven through a hill 150 fathoms high, for a length of seven furlongs. Its height and width were each eight feet, and it conveyed the water from the river Ampelus into the city. Herodotus tell us that the architect was Eupalinus, the son of Naustrophus, a Megarian. Sir George Wilkinson, in a note on the text, mentions the fact that a French traveller, M. Guérin, discovered one mouth of this tunnel to the N.W. of the harbour of Samos, and cleared it from sand and stones to a distance of 540 paces.

It is sometimes asserted that the ancients were ignorant of the hydrostatic law that water finds its own level. This is not the case. Frontinus, who preceded Agricola, the father-in-law of Tacitus, as Governor of Britain, and who was Curator Aquarum in Rome under Nerva and Trajan, mentions in his book, 'De Aquaeductibus Urbis Romae,' that in case of the fracture of an aqueduct, the water could be dammed up at each side of the point of fracture, and carried over the intervening space in leaden pipes. A great deal of the internal distribution of the water in Rome was managed by leaden pipes under pressure.

The aqueduct which Herod is said to have constructed for the supply of Jerusalem crossed a deep valley—near Rachel's Tomb—by means of a stone pipe working under pressure. This work has been fully described by Mr. Telford Macneill in the Report made by Sir John Macneill to the Committee for supplying Jerusalem with water. The construction of this pipe is so remarkable that I shall give Mr. Macneill's description in detail. It consists of great blocks of stone through which holes 15 inches in diameter have been cut. One end of each block has been hollowed out to a depth of 4½ inches, with a diameter of 24 inches; thus leaving a recess 4½ inches wide to form the socket of the pipe. The other end has a projection of a size to fit a similar socket in the pipe which lies next to it. This answers to the spigot of a modern cast-iron water-pipe. Both socket and spigot are ground, so as to fit with great accuracy, and the joint is made with cement, which has set as hard as the stone itself. The whole line of these stone pipes is surrounded with rubble masonry. The pressure on the centre of this very remarkable inverted syphon is not less than 70 lbs. per square inch.

The Arabs at a later period not only knew of this law, but also understood the operation of what we engineers call the "*hydraulic mean gradient*." The aqueducts constructed by them for supplying Constantinople with water have been very fully described in those most interesting 'Letters from Turkey,' written by Field-Marshal von Moltke in the years 1835 to 1839. He says that the Arabs knew that water under pressure reaches its own level (*sich gleich stellt*), for they conveyed the water across the valleys in leaden pipes. They had found by experience that the friction through the aqueduct was lessened if openings were made in the course of the line of pipes; and along hill-sides and in places where the pipes were not in deep cuttings, funnel-shaped shafts or wells were made, which acted as air-holes. But in crossing deep valleys, where, of course, no such holes could be made, they built stone pyramids, called "Suterasi," or water-balances, on the top of which they placed small basins, into and out of which the water was conducted by a leaden pipe laid up one side of the pyramid and down the other. The level of these basins was so arranged that they were at an inclination rather

greater than the average fall of the aqueduct; and thus they allowed the water to take the hydraulic mean gradient due to the head necessary for the delivery of the water. It is probable that these "suterasi" were made about 1000 A.D.

For 400 or 500 years after the last date very little was done in the way of great public works of this description; and it was not until the beginning of the sixteenth century that the state of the rivers in Italy commanded the attention of the great landowners and scientific men of that country. At that time, chiefly in consequence of the appointment of a Commission in 1516 by Francis I., works for remedying existing evils were seriously thought of; and for a long series of years the most eminent mathematicians and engineers were engaged in investigating the subject and in designing and carrying out works of greater or less magnitude. A very full collection, both of the writings of these Italian engineers and of descriptions of their works, is contained in a book of thirteen volumes, published at Bologna, in 1821-24, entitled 'Raccolta d'Autori Italiani che trattano del Moto dell'Acque.' It would seem that about the same time the question began to excite interest in England, for it was in the reign of Henry VIII. that a public statute first dealt with river conservancy. But it is to be remarked that neither in Italy nor in England was the question treated in anything like an exhaustive manner. The great hydraulic works of Italy relate almost exclusively to irrigation and navigation, whilst the drainage of lands and the prevention of floods were the objects of legislation in England. During the same period the Dutch were of course constructing many important hydraulic works; but these, from the special circumstances of the country, were not such as to have much bearing on the general question of the conservancy of rivers.

After the drainage of the Fens, the next great works in England were the canals, which, in a very few years, extended over the whole of England, and formed a complete system for the conveyance of traffic. It is superfluous to say that their construction and maintenance had a strong bearing upon the regulation of rivers. The well-known saying of Brindley that rivers were "principally valuable for feeding canals" sufficiently indicates the subserviency of the other interests involved. Next, the introduction of railways and steamboats, and the increase in the size of ships, turned the attention of those interested in rivers to the improvement of the tidal harbours and channels; and from that time to the present the greatest hydraulic works of our time have been connected with navigation. The concurrent increase in manufactures necessitated the employment of water in ways apparently antagonistic to other interests, and introduced the new element of pollution of our rivers and streams, whilst the demands of sanitary legislation consequent on the great increase of population made it imperatively necessary that their purity should be maintained. Indeed, we may say that the present high state of civilization in which we live has involved greater complications in this as in other departments of life, and requires special arrangements to meet them.

Legal enactments for the regulation of rivers, and for defining the rights of property in water, have existed from very early times. Solon laid down that to intercept the supply or to corrupt the quality of water is a crime. He also enacted that if any one dug a well to a depth of ten fathoms (ὀργυῖαι) without finding water, he should be permitted to take from his neighbour's well a pitcher of six χόες (about 18 quarts) twice a day. Plato, in his Laws, mentions an analogous provision, but confines it to drinking water only. Another law quoted by him is more to the point: it runs as follows: "If after heavy rains any of the lower riparian proprietors should injure a neighbour who lives above them, by stopping the downward flow of the water, or in case, on the other hand, the proprietor living higher up shall injure his neighbour below, by negligently allowing the water to run down upon him, either of them may call in the magistrates and obtain a decision for the guidance of both parties. If either party fail to abide by such decision, he shall be punished for the enviousness and peevishness of his spirit, and shall pay double damages to the injured person."

The Pandects of Justinian, which are a collection of all the old legal authorities of Roman Law, analogous to our own Reported Cases, contain a variety of leading

principles which govern the administration of the law of running water: principles identical mainly with that of our own Common Law. Some of these related to fishing, watering cattle, to the interruption of navigation of lakes, canals, and ponds, to the preservation of the water supply, to the repairs of river banks, and to the regulation of the summer and winter flow of what were termed public rivers. It was enacted among other things, that nothing should be done to the stream or banks of a public river, whereby the flow should be altered from its state in the preceding summer.

The earliest record in our own Statute Law of any enactment relating to rivers is that contained in 25 Edward III. c. 4, which legalised all "gorces, mills, wears, stanks, stakes, and kiddles" of a date previous to "the reign of his grandfather Edward I. by which the common passage de neefs et batelx en les grantz rivers d'Engleterre be oftentimes annoyed," and ordered the immediate pulling down of all such erections which were of a later date.

From that time, until the enactment of Henry VIII., there were various laws passed, chiefly relating to the navigations and rights of mills, and occasionally to the preservation of fish. After Henry VIII. very many private Acts and Charters granting powers for the drainage and reclamation of lands, for improvement of navigation, and matters of a similar kind, were passed from time to time. A great number also of Royal Commissions and Select Committees have conducted enquiries, and made reports upon most of the various branches of the subject, e.g. the pollution of rivers, the water supply, arterial drainage, navigation, fisheries, &c., but, until the appointment last year of the Select Committee presided over by the Duke of Richmond, no attempt, as far as I am aware, has been made to grapple with the question as a whole, and the Report made by them to the House of Lords omitted to deal with, at least, two of the objects I have indicated as being necessary to the proper consideration of the subject.

The recommendations made in the Report of that Committee were most important, and they will, if carried out, remove many of the difficulties which stand in the way of a complete system of conservancy of our rivers.

So much has been written on the engineering details of this subject, by men far better qualified than I am to deal with them, that I shall confine myself to the simple statement of the principles which have been recognised by the chief authorities as essential, and to a few suggestions, which my own experience leads me to think may be of some value. Almost all the great engineers of former generations, who have paid attention to this question, Smeaton, Telford, Rennie, Golborne, Mylne, Walker, Rendel, Stephenson, Jessop, Chapman, Beardmore, and without mentioning names, many of the most eminent now living, have agreed to the following general propositions:

That the freer the admission of the tidal water, the better adapted is the river for all purposes, whether of navigation, drainage, or fisheries.

That its sectional area and inclination should be made to suit the required carrying power of the river throughout its entire length, both for the ordinary flow of the water, and for floods.

That the downward flow of the upland water should be equalised as much as possible throughout the entire year; and

That all abnormal contaminations should be removed from the streams.

In carrying out these principles, it is perhaps superfluous to say, that modifications must be introduced to suit the particular phenomena of each river. In some watershed areas, it would be easy to construct reservoirs, which would to a great extent equalise the flow and reduce floods. In others it might be better to control the floods by means of embankments. In others, to have weirs, and sluices, delivering into side channels, parallel to the main stream, with the same object. Sometimes reservoirs, or receptacles, must be made for catching the *débris* brought down by the streams. In fact, every river must be treated as a separate entity. It is therefore, necessary that a systematic collection of data, relating to rainfall, the geological character of the gathering ground, and the volume of each separate stream, should be made for each watershed area; and this should be carried on for a sufficient length of time to enable a fairly correct estimate to be formed of the

behaviour of the river both in time of flood and in time of drought. The establishment of self-acting tide-registering gauges at several points of every outfall should be insisted on. By these means the whole of the phenomena of a watershed area could be ascertained and recorded, and safe and trustworthy knowledge could be obtained, which would contribute towards the determination, not only of the works which ought to be executed, but of the incidence of the taxation by which the necessary funds should be raised. For instance, it is obvious that where the geological character of a watershed is variable, one portion of it consisting of a permeable stratum, such as chalk or red sandstone, and another portion of an impervious stratum, such as the tertiary clays or the shales of the millstone grit, the same works would not be adapted to each section of the river, nor would it be fair to charge all with the expense according to the same scale of contribution. The former, that is the permeable stratum, is not only, from its absorbent nature, not the cause of floods, but is, by reason of that characteristic, absolutely constituted by nature one of the very works which must be devised by art to mitigate the effects of rainfall on the latter, or impervious stratum.

Bearing this in mind, I have often thought that nature might be usefully imitated in this operation, by passing the surplus rainfall into the permeable strata of the earth by means of wells, or shafts, sunk through the impermeable strata overlying them. This has been done in isolated cases for the drainage of lands, but not for the deliberate purpose of preventing floods and equalising the flow of rivers.

I also wish to remark that artificial compensating reservoirs may be much more frequently made use of than is generally supposed to be possible, when it is considered that, so long as the dams are constructed in situations where there is no danger of their giving way, it is by no means necessary that they should be water-tight, and that, therefore, they can be constructed at a very much smaller outlay. In fact, the purpose would be answered by a series of open weirs, which would collect the water in times of flood and discharge it gradually down the stream.

The example of our French neighbours in the more general use they make of moveable weirs—*barrages*—of various constructions could, I am satisfied, be followed by us with very great advantage in many cases.

The question of water power is one which I think deserves more consideration than it has lately received. It has been the fashion to consider that small water-mills are of little or no value, and, in the present state of most rivers and streams, this is to a very great extent true, but only because the supply of water to work them is so variable and uncertain. Sufficient attention has never yet been given to the subject of the amount of compensation water which should be given for the use of riparian proprietors when the watershed areas are dealt with for purposes of water supply. There is a kind of empirical rule acknowledged by most of the eminent water engineers, that one-third of the average flow of three consecutive dry years is a fair equivalent for the abstraction of the water falling on a gathering ground. I am strongly of opinion that, looking to imperial interests, advantage should be taken of every opportunity of dealing with a gathering ground to provide for a much larger proportion of its available water being sent down the streams, so that the natural water power of the country may be properly developed. The extra cost of the necessary works must, as a matter of course, be borne rateably by the interests benefited. It is certain that with the progress of invention many more ways of utilising this power will be discovered. At present, through the medium of compressed air, of hydraulic pressure, and of electro-motors, the great disadvantage of its being only available at the spot where the water runs is overcome, and the power can be transmitted to any distance, and used wherever it may be most conveniently applied.

Sir Robert Kane, in his most valuable and exhaustive work on the 'Industrial Resources of Ireland,' has given an estimate of the value of the power allowed to escape every year in the shape of floods, and the same calculation might be applied to the sister kingdom. It is probably no exaggeration to say that where running streams exist the power required for estate purposes, on the majority of

properties in the United Kingdom, might be obtained by a proper conservation of the natural water resources of those streams.

The consideration I have been able to give to this subject has helped to convince me that, although a vast amount of labour and research has been devoted to it, it is nevertheless one in which "a more systematic direction to scientific inquiry" is urgently needed.

A vast collection of scientific facts exists, but they require arrangement and collation, and future observations should be more strictly classified, so that the bearing of each one, both on the others and on the subject at large, may be properly appreciated with a view to a practical result.

In France this is being done to a very large extent, and an excellent Map showing the phenomena of the rivers and streams of that country is now in course of preparation. For many years also very accurate observations of the phenomena of the whole of the basin of the Seine have been taken, and have been centralised (*centralisées*) by that eminent engineer, whose loss all who had the privilege of knowing him either in his work or in private intercourse are deploring, M. Belgrand, late Inspector-General of the Ponts et Chaussées, and by his able coadjutor, M. M. G. Lemoine. These observations have been published in the form of diagrams, admirable in their simplicity of design, which show at a glance the bearing of every one of those phenomena on the general character of that river.

In Italy also, where there exists a distinct department having control of the hydraulic works of that country, the same exhaustive system of collation and record has been followed, and the results have been published in a series of tables. In Germany, although the same complete system is not in vogue, its chief river has been the subject of most thorough investigation, the results of which have been published in a beautiful map of the Rhine and its regulating works.

In our own country, as might be expected from the number of engineering works which have been executed, there probably exists an amount of detailed information on special and often minute points which is unsurpassed, and probably unequalled in the world.

But, although as I have said before, a great number of eminent men have treated in an exhaustive manner the phenomena relating to many of the principal rivers of Great Britain and Ireland; yet, as far as I am aware, there has been no attempt to collect and combine these most valuable, though detached fragments of knowledge, so that their relation to one another might be seen, and a general conclusion arrived at. This can only be done by the establishment of a public department analogous to those described as already existing in France and Italy.

I do not wish it to be understood that in suggesting the collection of additional data relating to the phenomena of rivers, I am advocating delay in dealing with the existing state of things until the facts have all been ascertained. On the contrary, I believe that the first step ought to be the establishment of a distinct Water Department, which should at once address itself to the remedying of the evils which are found to be most pressing. The time has long since arrived when the present neglected state of many of our most important streams should be dealt with, and that this was also the conviction of Parliament and of the Government is evident, from the appointment of so influential a Committee as that presided over by the Duke of Richmond last session.

Even the imperfect sketch which I have been able to place before you will have made manifest, I think, the enormous importance of the subject and of the interests involved—interests subject to periodical losses arising from the present imperfect organisation, or, I may say, the present entire want of organisation;—losses which are not only monetary, and therefore to a certain extent capable of being estimated, but which affect health and imperil life, and on that account, as is the unhappy experience of the highest as well as the lowest of the community, utterly incapable of appreciation. How, for instance, can we estimate the loss sustained by the country at large by the premature death of that noble-minded and accomplished gentleman, the Prince Consort, whose life and energies were devoted to the encouragement of all the objects which this Association is established to foster and promote, and who showed

his strong sense of its usefulness by presiding at one of its most brilliant meetings.

When it is considered that many lives are annually sacrificed, either directly by the action of floods, or by the indirect but no less fatal influence of imperfect drainage, —when it is remembered that a heavy flood, such as that of last year, or that of the summer of 1875, entailed a monetary loss of several millions sterling in the three kingdoms,—that during every year a quantity of water flows to waste, representing an available motive power worth certainly not less than some hundreds of thousands of pounds,—that there is a constant annual expenditure of enormous amount for removing *débris* from navigable channels, the accumulation of which could be mainly, if not entirely prevented,—that the supply of food to our rapidly growing population, dependent, as it is at present, upon sources outside the country, would be enormously increased by an adequate protection of the fisheries,—that the same supply would be further greatly increased by the extra production of the land when increased facilities for drainage are afforded,—that, above all, the problem of our national water supply, to which public attention has of late been drawn by H.R.H. the Prince of Wales, requires for its solution investigations of the widest possible nature, I believe it will be allowed that the question, as a whole, of the management of rivers is of sufficient importance to make it worthy of being dealt with by new laws to be framed in its exclusive behalf.

A new department should be created—one not only endowed with powers analogous to those of the Local Government Board, but charged with the duty of collecting and digesting for use all the facts and knowledge necessary for a due comprehension and satisfactory dealing with every river-basin, or watershed area in the United Kingdom—a department which should be presided over, if not by a Cabinet Minister, at all events by a member of the Government who can be appealed to in Parliament.

The department should have entire charge of, and control over, all estuaries and navigable channels, both because these are used by foreign vessels, and therefore the responsibilities attaching to their preservation are international, and because they must be protected from hostile attack, and on these accounts are essentially Imperial property. For the same reason the cost of amending and maintaining them should be defrayed out of the Imperial exchequer.

As regards the regulation of the remainder of the watershed area, the conclusions arrived at in the Report of the Duke of Richmond's Select Committee seem to me entirely satisfactory. I cannot do better than give a few extracts from that Report. The Committee say—"That in order to secure uniformity and completeness of action, each catchment area should, as a general rule, be placed under a single body of Conservators, who should be responsible for maintaining the river from its source to its outfall in an efficient state. With regard, however, to tributary streams, the care of these might be entrusted to District Committees, acting under the general direction of the Conservators, but near the point of junction with the principal stream they should be under the direct management of the Conservators of the main channel, who should be a representative body constituted of residents and owners of property within the whole area of the watershed." The Committee go on to say that "means should be taken to ensure the appointment of a Conservancy Board for each watershed area," but that application should first be made by persons interested in the district, and that then the departmental authorities should send inspectors to make local inquiries and to report upon the "necessities and capacities of the district, and suggest the area and proportions of taxation."

The scheme with such modifications as may be deemed necessary is then to be embodied in a provisional order, to be submitted to Parliament for confirmation. It will be seen that this mode of procedure is precisely analogous to that of the Local Government Board in relation to public health—a procedure which, as I am able to state from practical knowledge, works admirably in most cases. The Committee further recommend that the provisions in any local or other Acts which would interfere with the proposed scheme, should be repealed. They are also of opinion that "the Conservancy Boards should be enabled to execute the powers

conferred on local authorities by the Rivers Pollution and Prevention Act." It will also be necessary that their powers should extend to the carrying out of any Acts passed or to be passed for the protection of the fisheries.

With regard to what is probably the most important point of all, the finding of the money necessary to carry out these recommendations, the Committee advocate the introduction of a new principle of taxation, the soundness of which cannot be questioned. Instead of the principle first introduced by the statute of Henry the Eighth, and observed ever since, of levying taxes in proportion to the direct benefit conferred, the Committee propose that the rates should be distributed over the whole area of a watershed, including not only the lands, but the towns and houses and all other property situate within that area. This is in fact no more than a general application of the law of highways, which in the time of the Romans, according to Justinian, applied equally to waterways. It is perfectly just that every acre, the drainage of which contributes to the flow of the streams and rivers of every watershed area, should, in some proportion or other, contribute also to the cost of maintaining the channels of those streams and rivers in an efficient state. The incidence of the taxation must of course, as has been pointed out, be determined by the circumstances of each particular case, but there is no doubt that the conclusion of the Duke of Richmond's Committee, that "the taxation should be levied on the basis of rateable value," is the only sound, and at the same time practical, way of dealing with this difficulty.

The word "taxation" is not, I fear, generally connected with any idea of profit to the individual taxpayer. But in this case, as I hope in the course of this address I have made clear, it is probable that the prevention of large present losses, and the advantages gained by an improved system, will give not only a fair but an ample return on the capital expended.

It is my firm belief that an intelligent management of watershed areas would be compatible with an absolute profit to every interest affected; that we have here no question of give and take, but that in this, as in every other case, the laws of Nature, under proper and scientific regulation, can be made subservient to the needs of the highest civilisation.

The following Papers were read:—

1. *On River Control.* *By* J. Clarke Hawkshaw.

The author, after alluding to the growing importance of the question of river control, pointed out the difficulties with which engineers have to contend when called upon to deal with rivers piecemeal, owing to the divided jurisdiction to which the rivers of this country are subject, and to the want of systematic observations on them. The different jurisdictions to which the river Witham is subject were given as an example. He then endeavoured to show that the works required for the purpose of land drainage, navigation, and water supply were so connected that they should be carried out under one authority. In conclusion, he advocated the appointment of a commission for each river basin, with powers to carry out works, and to rate all the land in the drainage area for that purpose; the rate to be an equal rate levied on all the land, whether covered by buildings or not, according to its annual value, with the exception of lands liable to floods, which should be rated at a higher rate until the works for prevention of the floods were carried out.

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2. *On the Effect of River or Arterial Drainage Works upon River Floods.* *By* James Dillon, *Mem. Inst. C.E.I.*

In this paper the author pointed out the large amount of damage done to properties in different countries by river floods overflowing their banks, such as the Thames, Shannon, and other large rivers, and although much had been done throughout the country to prevent flooding, still much remained to be done. It was shown that year by year the applications for loans of money to carry out river

or arterial drainage works in Ireland were becoming fewer in number, until last year there was only one application received by the Commissioners of Public Works, although previous to 1863 the Drainage Commission (Ireland) relieved 266,736 statute acres from floods at a cost of £2,390,612 under the Act 5 and 6 Vict., and since 1863 down to July 1878 over 71,000 statute acres were drained by a further expenditure of £389,000 by Drainage Boards formed under the Act 26 and 27 Vict., c. 88; the total number of drainage districts amounting to 157, of which 37 were carried out under the last-named Act.

The author stated that it frequently happened that when a number of lowland proprietors promoted a scheme for the improvement of their larger, and consequently more costly sections, they generally tried to tax the upland proprietors for some of the additional outlay, and the latter then resist the attempt; while if the upland proprietors try to improve their smaller and less costly rivers, they are opposed by the lowland proprietors, who contend that such works, by the drainage of the uplands, would increase their lowland floods. This kind of opposition renders it very difficult to obtain assent to the execution of works from the owners of two-thirds of the injured land.

The author stated his belief that such objections should not be allowed to have weight, because, from experiments made by him on flood discharges before and after the execution of extensive river or arterial drainage works, he found that such works had *not* the effect of increasing the river floods either above or below the termination of the works. The reasons given for this result are as follows.

It has been proved that the area of land actually covered by flood water (with scarcely an exception) seldom exceeds seven per cent. of the entire catchment-basin, or area of land unwatered by rivers, and in 120 districts completed by the Irish Drainage Commissioners the flooded land did *not* amount to seven per cent. of the total area of the catchment-basins, and that this seven per cent. of flooded land was generally to be found along the river banks or shores of lakes affected by the rivers.

It also happens that this three, four, or seven per cent., as the case may be, is always more or less saturated with water, particularly in winter, and that when so saturated any additional flood waters coming on it will rise and flow over its surface.

It is believed by many that the waters covering a river valley in flood times are stationary. This might be so if the river valley had no fall or inclination in the direction of its length; but without some such fall the flood waters of former times could not have scooped out, as it were, a river, however insufficient and imperfect it may have been; therefore it is a fact that, unless in very exceptional cases, the floods in river valleys continue to move towards the natural outfall for each valley.

It is also known that every flooded river valley has its fixed maximum flood marks, beyond which the floods never rise. and if, when the floods reach this level, rain should still continue to fall, then the whole of the floods due to this additional rain must reach the river valley, passing away as quickly as they arrive, or the flood levels would rise in the valley.

If, then, the whole maximum flood due to continuous rain passes from an upper to a lower division of a district, in the natural flooded state of a district before arterial drainage works are carried out, then it would be impossible that the deepening or enlargement of so many miles of a river could increase the floods or rainfall either above or below the improved section of the river.

It should be remembered that, before the execution of such works, just in proportion as the rainfall ceases, so would the floods subside, were it not that towards the termination of the rainfall they are largely increased in volume by the escape of the flood-waters that previously overflowed the river banks.

It may be said, if the effect of arterial drainage works is to prevent the accumulation of large sheets of flood waters in a river valley, then the floods must be increased by the passing away of these waters.

This the author believes to be a mistake. For up to the present time he has expended on main and tributary river works (sanctioned by Government) of an aggregate length of 150 miles, nearly half of the whole amount expended on such works in Ireland since 1863. As all these works proved successful, both from a scientific and financial point of view, he was afforded opportunities of observing the flood discharges before and after the execution of such works as the Inny River Works,

where the flood waters were collected from 273 square miles. It has been already stated, that the flooded ground seldom averages seven per cent. of the catchment-basins, and in the Inny District, above referred to, it equalled an average breadth of 1237 feet, or seven per cent. If, then, a number of tributary rivers, with catchment-basins some two miles in breadth and some eight or ten miles in length, branch off at nearly right angles to the main river along which this seven per cent. flooded land exists, then if you divide these lateral catchment-basins each into 100 parts, allowing the seven parts near the river to be flooded, it will be evident that the maximum flood due to the maximum rainfall on the seven parts or seven per cent. at the junction of the tributaries with the main river will have passed away into the main river before the maximum floods from the second, third, or tenth miles, &c., could reach the last-named junction, provided the rivers were not dammed up with shoals, &c.

So that the time required to allow of the river valleys being covered with water before the execution of the works would, if properly utilized, be more than sufficient to allow of the water passing down a properly constructed river-channel before the maximum floods could reach the main river from the second, third, or tenth mile back from the main river.

If this holds good in narrow tributary catchment-basins, so will it be applicable to all forms of catchment-basins, no matter what their direction with regard to the main channel.

The author believes, then, that the effect of arterial drainage works is to enable the floods from the fractional 4, 7 or 8 per cent. flooded lands, near the main arteries, to pass off after the execution of the works many hours or days sooner, according to the magnitude and length of the rainfall and district, than before the execution of the works, and that, by securing a longer interval of time for the discharge of a flood of given magnitude, arterial drainage works cannot increase the maximum flood-discharges of a district.

As this view of the case is confirmed by the author's observations, he invites discussion in order to test its accuracy.

When once it is established that the floods in a river valley are not increased by the enlargement or improvement of either an upper or lower section of the river passing through the valley, the author believes that the public and the Government would find it more practical to deal with the improvement of rivers in the following way.

Whenever any considerable portion of a country is flooded by the overflow of a river or its tributaries, and the parties injuriously affected are desirous of applying to Government, through the Commissioners of Public Works in England, Ireland, or elsewhere, for a loan to improve their land, they should be required to furnish a section of the rivers to be improved, taking care to extend the sections down the river whether 1 or 100 miles in length until a sufficient outfall is obtained for the successful carrying out of the proposed works.

Should the Board of Works report in favour of the project, the Treasury could, after the usual formality, advance the necessary funds, thus enabling useful works to be carried out under the superintendence of Drainage Boards acquainted with the localities with which their interests are connected, instead of losing many years in endeavouring to embrace all the tributary districts in one large, costly, and unmanageable scheme. By this method the works could be commenced in divisions corresponding to the natural sub-outfalls of the country, commencing at the fall nearest to or furthest from the sea.

Should this method be sanctioned by Government on any large scale, now that it is proposed to grant loans for river works on a moiety of the proprietors assenting to the project, instead of requiring two-thirds as formerly, a great impetus would be given to the extension of such works, conferring great benefits upon the country by increasing the value of land, and giving at the same time additional employment, and circulating large sums of money among the working classes in agricultural districts.

Although the facts thus briefly set forth in this paper are now publicly brought forward by the author for the first time, still in the case of the Great Barrow River Scheme, which embraces a country of 625 square miles, he has succeeded in

overcoming hostile opposition (based upon increased flooding) to its being executed in divisions instead of in one unmanageable whole. Of this work two divisions have already been sanctioned by Parliament and are now nearly completed. The object of the author in bringing forward these facts is that the practicability of dealing with large river systems in divisions, instead of in one whole, may become more universally known and acted upon.

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3. *On the Control of Rivers.** *By* W. SHELFORD, *M. Inst. C.E., F.G.S.*

The author divided the subject under two heads—I. *Tidal Rivers.* After showing that the importance of British rivers was due to tidal water, and that the tidal portions of them had been subject to the care of the Government as early as Charles II., he gave instances of the divided control which existed down to 1867 between the several departments of the Government itself.

He alluded to the Thames as a case where the controlling bodies—the Thames Conservancy and the Metropolitan Board—were now divided even as to the fact of the existence of sewage pollution; and he referred to Smeaton's Grand Sluice on the Witham as an example of injury undoubtedly done a century ago, and still felt, through the divided control exercised by the land and navigation interests.

Passing on to the Fen rivers, he gave in considerable detail the results of an attempt to improve the Nene on sound engineering principles, which was rendered abortive by its failing to combine sufficiently the various interests, and drew therefrom the conclusions:—

1st. That such works should be undertaken on a financial basis which will secure their completion, and

2nd. That the taxable area should be as extensive as possible.

II. *Rivers not tidal.* He denied that fresh-water rivers could be compared with tidal rivers, and instanced the difference between the floods of the Tiber and the Thames.

He illustrated the present condition of the fresh-water portions of our rivers by details of the Upper Nene, where the ratio of flood to dry weather flow was 430 to 1; of the Cray and Darent (tributaries of the Thames), where the flow was in the former nearly uniform, and in the latter the ratio of flood to drought was 16 to 1, thus showing the different treatment required in each case; and after giving reasons for stating that, in the absence of a comprehensive conservancy, the jealousy of the mill-owners and other riparian proprietors had led on the Nene to a scramble for fresh water, and on the Cray to the use of excellent water chiefly as a carrier of refuse; and that the Darent presented a unique example of a valley in which the watershed had been adopted as the boundary of the rateable area, he classed the several functions of a stream passing through a highly civilised community (though the order of merit varied) as—1st, water-power; 2nd, water supply; 3rd, carriage of refuse; 4th, navigation; 5th, purity equal to at least the preservation of fish, and stated that each of them was now guarded independently and without any comprehensive plan or control. His general conclusions were:

1st. That each river or tributary must be treated as a whole within the boundary of its watershed.

2nd. That all public works within the watershed should be under one undivided control.

3rd. That the rateable area for these purposes should be conterminous with the watershed.

4th. That the minimum flow of streams liable to floods should be increased by storage.

5th. That the separation of good from foul water, the collection and distribution of wholesome water, the discharge of sewage, the improvement of the channel both for conserving the dry weather flow and for dispersion of floods, the maintenance and improvement of tidal reservoirs and navigable channels, the removal

* This paper was published *in extenso* in 'Engineering,' November, 1878.

of shoals and the erection of piers, and the working of Acts of Parliament, must all come within the scope of the undivided control which he advocated.

He considered such an undertaking the more worthy of Government attention, because the requisite knowledge and experience would rarely be found in one man or one body of men, and was possessed by few even in the profession of civil engineers, who would necessarily have to occupy the most prominent positions and take the heaviest responsibility.

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4. *On Movable and Fixed Weirs, with reference to the Improvement of the Navigation, Mill Power, and Drainage of Flood Waters of Rivers, with especial Notice of the River Shannon.** *By* J. NEVILLE, *C.E., M.R.I.A., Dundalk.*

Most rivers in their natural state, even within tidal influence, are but a succession of pools and shallows of different lengths. the conditions of each, or its regimen, depending on the varying inclinations of the bed, its natural formation, the maximum, minimum, and average flow from the catchment-basin and tributaries at different seasons, the scouring of the bed and banks, and the formation of shoals or deposits. The steepest or shallowest portions, at rapids, are but the accelerated flow over natural submerged weirs of rock or coarse gravel cemented with clay and sand, and the pools between, long or short, or extending into lakes (those natural regulators of flood waters), constitute the deeper stretches of the river. Where the river alone has to be improved for a limited navigation, a sufficient depth at the shallows is sometimes obtained by running out spur weirs, thereby narrowing and deepening the water-way; or, by making a part of a continuous weir movable or removable, damming up the water at times of least flow, and passing down the craft employed, on flushes through the open movable portions of the weir which is again raised to retain the head. As, however, the application of this system of flush navigation is limited and only available for craft of suitable build, for down-stream traffic, the necessity arises for constructing locks with sometimes lateral navigable passes, or canals, along the shallows to connect the deeper portions of the navigable river channel above and below. The gates of such locks, with their sluices for working, are only movable weirs maintaining a fixed depth above at seasons when the flow is limited. In some states of the regimen I have occasionally seen lock-gates left open for a free navigation, the head being entirely maintained by the natural obstruction of adjacent submerged weirs at the shallows, and by back water from below.

The author, after classing the sluices and gates of movable weirs into those which lift in a plane, those which turn on a vertical axis, those which turn on a horizontal axis, and those that act on the principle of the American bear-trap sluice, used in 1818 on the Lehigh descending navigation, and having given different examples from French and Indian rivers, concluded with reference to fixed long weirs as follows:—Mill weirs are generally fixed and solid. When the water supply is limited and in dry seasons, a larger quantity can be stored by extending the weir basin or pond and lengthening the weir, at the same time the head for a variable supply is better regulated for a water-engine. To pass the same quantity of water over the crest, the head there can be reduced to one-half by trebling the length, and reduced in the ratio of two to three by doubling it. These advantages with reference to mills must have led to the misapplication of long solid weirs without even a sluice on the drainage and navigation works of the Shannon. Long solid weirs sloping or curved two or three times the width can have no practical advantage over those of the ordinary mean width from bank to bank, on long upper stretches of a river, without proportionately extending the width and depth the whole way. On the Shannon the upper obstructions in the bed between weir and weir were only partially removed, and the works remain in every way a sad monument for the riparian proprietors of an engineering failure.

* The paper has been printed *in extenso* in 'Engineering,' for Friday, August 23, 1878.

If for large rivers, where navigation only, without drainage, had to be considered, the necessary weirs to obtain sufficient sailing depth were made movable down to the bed even when locks were provided, as in France and India, with far greater reason should they have been made movable down to the bed on the Shannon, where the drainage of the *Callows* and low riparian lands was a part of the original design.

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5. *The Rainfall of Ireland. By* G. J. SYMONS, *F.R.S.*

The author mentioned that the Irish hills do not appear to exhaust the rain-clouds so much as the English hills do. With the exception of a dry central area round Dublin, the rainfall all over Ireland may be taken to be almost the same. At present, instead of the greatest rainfall being in the south-west, or in Galway, we had the wettest spot of all (with one exception) under the shadow of Slieve Donard, in the south of the county Down, the very place which, theoretically, might be expected to be almost the driest part of Ireland. That showed that it is really more a question of the elevation of hills than of geographical position. He exhibited a map showing the number of stations established for the observation of the rainfall, and the averages at many stations. From 1866 to 1876 there were thirty stations established, at which the rainfall was regularly recorded, and at those stations the fall in the ten years was not very different from that in the five years 1872-76. It was, therefore, a fair conclusion that the average from 1872 to 1876 was not far wrong. It might probably be wrong 3 or 4 per cent.

He had succeeded since the meeting of the Association in Belfast in obtaining the services of a large number of gentlemen volunteers throughout Ireland, who had taken charge of the rain gauges supplied to them, and had engaged to register their observations. There were still large districts, however, in which he had not been able to establish rain gauges, and the observations were, therefore, necessarily defective as to the average rainfall. There was a large district in the neighbourhood of Longford without a single station, and another in the south-west of Cork, where it was essential that observations should be taken. If he could induce some gentlemen having property in those neighbourhoods to take charge of rain gauges, Ireland, instead of having to depend upon ten stations, as it did not many years ago, would be fairly represented, both geographically and physically.

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6. *On the Hydrogeological Survey of England.* By* JOSEPH LUCAS, *F.G.S.*

The need of a National Hydrogeological Survey having been admitted at the Congress on National Water Supply at the Society of Arts, the author passes on to the consideration of how the information collected by the survey may be brought to bear so as to produce the result aimed at, viz., the improvement of the water supply of the country generally.

The product of the survey is a map, on which the necessities as well as the capabilities of each river basin are made to appear. The author proposes that on the completion of the map of the first (and each subsequent) river basin the Government should invite the competition of engineers to frame comprehensive schemes of a distributary character, based on the watershed area, and should appoint a special commission to examine and report upon such schemes. When this commission had rendered its report, a Central Board, consisting of members of the Local Government Board, assisted by members elected from the various County Boards within the basin, should be created for the purpose of dealing with the water supply of each river basin. This Board should have rating powers over the whole basin, and the conservancy of the rivers, and would contain the elements for dealing with cases in which the requirements exceed the resources of the basin, and *vice versâ.*

* Published *in extenso* by the Committee of Section G.

FRIDAY, AUGUST 16, 1878.

The following Papers were read:

1. *On the Drainage of the Fenland considered in relation to the Conservancy of the Rivers of Great Britain.** *By* W. H. Wheeler, *M. Inst. C.E.*

The contention of the writer of this paper is that in the Fenland is to be found the type on which the future administration for the conservancy of the rivers of this country should be founded; that as in this large tract of land on the east coast of England the science of drainage has received more attention than in any other part of the kingdom; that as here various forms of administration for the management of four important rivers have been on their trial for long periods; that as by private enterprise alone immense sums of money have been sunk with a result that has placed this district in the very first rank as yielding corn, cattle, and agricultural produce of all kinds, so here our legislators may turn in order to learn what to copy and what to avoid; that the meeting of the British Association affords a fitting opportunity for bringing together the results of local experience and placing them before those interested in the subject with a fulness and freedom of expression which no Parliamentary inquiry can bring forth.

The great lesson the "History of Fenland Drainage" teaches is, that no scheme of improvement can be effectual unless the rivers are dealt with as a whole, and placed under one governing body from their source to their outfall; that the organisation of the administration for this purpose can only be effected by imperial legislation, and must not be of a voluntary nature. The whole government of the Fenland drainage is made up of piecemeal legislation; and although the administration of the several districts is thoroughly efficient, and the aggregate result superb, yet as each has sought only its own interest, all, more or less, are suffering from the defective condition of the common outfalls, large areas above the Fens being left without protection, and year by year subject to greater flooding. Had each river been originally treated as a whole from the source to the outfall, better results would have been secured, thousands of pounds have been saved, and much future legislation and outlay avoided.

The subject is treated in the paper under the three heads of Engineering, Administration, and Finance.

Under the first head it is sought to be shown that the object of all future legislation should not be drainage only, but the regulation of the water supply. The circumstances of our rivers having been altered by the modern system of drainage, it becomes necessary to adapt their channels to carry a vastly increased quantity of flood water at uncertain and distant intervals, and during the intervening period to discharge the diminished regular supply in such a way that the channel may not become choked by weeds and shoals, yet be made available for storing a supply of water in lieu of that which formerly percolated slowly through the soil. To effect this, a modification of the plan of wash-lands adopted by the old Fen engineers is suggested; the river proper being adapted for the ordinary summer and winter flow, the flood-banks to be set back sufficiently distant from the channel to leave a cess or margin to receive the flow of the greatest floods. The space thus left between the ordinary channel and the banks being only covered by water occasionally, would, like the wash-lands, afford valuable pasturage. The rapid voidance of the rainfall by the modern system of drainage leaving a diminished

* The paper, of which this is an abstract, has been printed *in extenso* by the Committee of Section G, together with the President's Address and the other papers on the same subject.

quantity to feed springs and afford a supply to brooks and watercourses, droughts have become more frequent. Fen experience here again suggests the remedy. In all the main watercourses and large arterial drains means are provided for holding up the water during the summer and periods of drought, and the streams thus become both carriers and reservoirs. The level of the water throughout the whole of the divisional ditches in the Fenland, and consequently of the soil itself, is always maintained at a fixed level, the loss by evaporation, &c., being supplied from the highland streams. Moisture is thus always within reach of the roots of the plants, even in the greatest droughts, and lands which would otherwise only be regarded as medium soils yield large and abundant crops. The writer is of opinion that the use of water in the cultivation of soil, and its value for purposes of irrigation is not sufficiently esteemed, and thinks that mills have received a great deal of undeserved blame for holding up the water, the effect of which is of the greatest benefit to the surrounding soil, when subject to proper regulations as to floods. The objection on sanitary grounds to the storage of stagnant water in the watercourses of the country is met by referring to the result in the Fens, the health and *physique* of the inhabitants of which compares favourably with every other part of the kingdom. By the erection of flood-gates, or properly constructed weirs across the rivers, a constant supply would be maintained to compensate for the excess carried off in floods, and to provide water for domestic, agricultural, and economic purposes. The value of water as a motive power in farm work is also contended for, and the saving of human labour and coals by this means pointed out.

To carry out the necessary improvements for regulating the channels of the rivers, and their future conservancy, a plan of administration adopted in certain Fen districts is proposed. Each watershed of a main river to be subject to one Conservancy Board, the whole watershed being divided into districts, the area of which is to be determined by the watersheds of tributary streams or other physical causes; the sub-districts to be placed under the jurisdiction of commissioners elected by the occupiers of the land in proportion to their rateable value, and who shall have the charge of all local interests; the general Conservancy Board to be elected from amongst the members of the District Boards, each sending one or more according to the area they represent, and to have control only over the main stream from its source to its outfall, and of all banks, sluices, and other works affecting it. Where districts are already in existence they would continue to exercise their rights and powers, except so far as they interfered with the main stream, and have their representative on the General Board. By this means the due care of local wants and interests, and unity of action throughout would be secured, and existing interests conserved so far as would be compatible with the general good.

The means for carrying out improvements required, and for future administration and maintenance, in the writer's opinion, should be provided by a tax on the rateable value of the whole area of land within the watershed, whether rural or urban. As every acre of land receives and contributes its quota of the rain-fall, so it should fairly provide its share of the cost of maintaining the channels for carrying this off. The objection that high lands can never be injured, and are so far away from the flooded districts that they do not require any improvement of the river, is met by the answer, that it is owing to the drainage carried out on these very lands that water is now poured so rapidly into the rivers as to cause the floods, and they ought, therefore, fairly to contribute towards the remedy for the evil they have caused. As to their distance from the outfall—the greater the distance, the greater use they make of the river, the water from the under drains of high lands at the head of a river having, perhaps, to travel a hundred times the length along its channel as compared to land within the area suffering from the floods. The objection that these lands have a prescriptive right to drain, and that to impose a new tax upon them would be an unjust burden, is met by the reply that the altered circumstances of the country necessitate fresh burdens, and the rates for police, education, and sanitary purposes are adduced as instances of novel burdens brought about by higher civilisation. Towns, it is contended, should bear also their share of taxation. Thorough drainage is a first essential for health, and this cannot be effected without a good outfall. By sewering the streets and bring-

ing a water supply from distant parts, towns have materially altered the normal condition of the discharge of the rainfall off the area they occupy, and during heavy rains send a large body of water into an already overcharged stream, and thus in a great measure contribute towards the flooding, while the withdrawal of the water necessary for the town takes away the supply from the springs which feed the upper part of the rivers.

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2. *On the Discharge of Sewage in Tidal Rivers.** *By* HENRY LAW, *M. Inst. C.E.*

A tidal river may be looked upon as a reservoir of a very elongated form, subject to the following conditions, namely:—

1st. That it is supplied with water of three different qualities from three different sources, that is to say—

The water constantly draining off the surface of the basin forming the watershed of the river, and that derived from the land springs which find vent in its bed; this we will designate *river water*.

The water entering the mouth of the river from the sea under tidal influence, which we will distinguish as *sea water*.

The polluted water discharged from the sewers, which we will term *sewage*.

2nd. That the actual and relative quantities of these are not constant, but vary within certain limits.

3rd. That the supply of *sea water* is not constant, but intermittent, being poured into the reservoir for a certain number of hours; and then for a certain period the reservoir being allowed to discharge a proportion of its contents.

Now the subject of our inquiry is, what, under the conditions assumed above, will be the mean or average composition of the water contained in the reservoir or river?

In order to obtain a practical result, let us investigate this question, adopting the mean values for the several quantities which apply in the case of the river Thames.

First, then, as to the extent and capacity of the reservoir. The tidal portion of the river Thames extends from Yantlet Creek to Teddington Lock, a total distance of about 60¼ miles; its breadth varies from about 200 feet to 22,800 feet, or about 4⅓ miles, at its mouth; its superficial area at high water is 720,594,410 square feet, or nearly 26 square miles.

The mean range of the tide at the mouth—that is, at Yantlet Creek—is 14 feet, at London Bridge 17 feet 4 inches, and at Teddington Lock 3 feet.

The mean tidal capacity of the river, that is to say, the difference in the quantity of the water which is contained by the river at high water and at low water, with the above-stated mean range of tide, is 14,179,538,300 cubic feet.

Now, as has been already stated, this body of water is derived from three sources—namely, the sea, the land drainage, and the sewage; and it is necessary in the next place to ascertain the relative quantities furnished from each of these sources.

The downward flow of the Thames, or, in other words, the mean daily discharge from the drainage of the Thames Valley, may be estimated at 1,923,626,000 gallons, a quantity which, we may incidentally remark, is about one-third of the rainfall.

From the above, however, must be deducted 100,000,000 gallons which is daily abstracted from the river above Teddington Weir for the supply of water to the metropolis; leaving a total quantity of 1,823,626,000 gallons, or 291,780,160 cubic feet, for the mean daily discharge, being 145,890,080 cubic feet as the mean quantity of *river* water contributed each tide.

The mean quantity of the sewage discharged into the Thames from the two outfalls at Barking and Crossness may be taken at 120,000,000 gallons daily, equivalent to 9,600,000 cubic feet every tide, making with the river water a total of 155,490,080 cubic feet, which being deducted from the mean quantity already

* This paper was published *in extenso* in 'Engineering,' for August 30, and in the 'Journal of Gas Lighting,' for September 3, 1878.

stated as that which enters the river every tide, we have 14,024,048,220 cubic feet as the mean quantity of sea water which enters the Thames every tide.

It is difficult to form a true idea of the relative values of such large numbers, and therefore it is better to reduce them to a percentage, when we obtain the result, that the mean composition of the Thames water is as follows, namely:—

Sea water	98·91
River water	1·02
Sewage water	·07
	100·00

That is to say, the actual mean quantity of sewage in the tidal portion of the river Thames, extending from Teddington to Yantlet Creek, is only 0·07 per cent., or otherwise expressed, only one 1477th part of its whole bulk.

Furthermore, it must be borne in mind that, owing to the circumstance of the river water always being delivered at the upper end of the elongated reservoir, no less than 60 miles in length, while the ultimate discharge is wholly from the lower extremity, the composition of the water varies greatly, being always much freer from sea water and sewage in the upper portion than the lower. In point of fact, it must be evident that, in the case of a stream which has a certain quantity of river water, that is, as we have already defined it, water derived from the rainfall and discharged into the river by surface drainage and land springs, there must always be a point, even in the tidal portion, above which no contamination can exist from sea water or other matters which enter the river near the lower portion of its course.

The foregoing is a statement of the average result; the actual amount of contamination by sewage at any given time and place must depend upon the recent past rainfall, and upon the state and condition of the tides, but at no time, and under no circumstances, can the amount of the sewage contained in the Thames water be raised sufficiently above its average value of one 1477th part to produce any appreciable pollution, far less to afford any ground for the statements to which previous allusion has been made.

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3. *Recent Improvements in the Port of Dublin.* *By* B. B. Stoney.

This communication was ordered by the General Committee to be printed *in extenso* among the Reports.—See above, p. 167.

SATURDAY, AUGUST 17, 1878.

The Section did not meet.

MONDAY, AUGUST 19, 1878.

The following Papers were read:—

1. *Report of the Committee on the Patent Laws.*
See Reports, p. 157.

2. *Report of the Committee on the use of Steel for Structural Purposes.*
See Reports, p. 157.

3. *Report of the Committee on the Steering of Screw Steamers.*
See Reports, p. 419.

4. *On the Steering of Screw Steamers.*
By Professor OSBORNE REYNOLDS, *F.R.S.*
Incorporated in the Report of the Committee on the same subject.

5. *General Results of some recent Experiments upon the Co-efficient of Friction between Surfaces moving at High Velocities. By* Captain DOUGLAS GALTON, *C.B.*, *F.R.S.*
See above, p. 438.

6. *Recent Improvements in Telegraphic Apparatus. By* W. H. PREECE.

7. *The Filtration of Salt from Sea Water into Wells in the Trias Sandstone.*
By I. ROBERTS.
See above, p. 532.

8. *Description of a new Lift Bridge for the Midland Great Western Railway, over the Royal Canal at Newcomen Bridge, Dublin. By* BINDON B. STONEY, *M.A.*, *M. Inst. C.E.*

This bridge carries a short branch of the Midland Great Western Railway of Ireland across the Royal Canal immediately below Newcomen Bridge, at the very

oblique angle of 25 degrees and, though the canal is only 15 feet wide, the bridge carrying the railway requires to be nearly 40 feet long on the skew.

The trains run over this bridge at about two feet over ordinary water level, and whenever a boat is passing along the canal the bridge is lifted from 8 to 13 feet, according to the height of the deck load, so as to permit the boat to pass beneath. The bridge is formed of two strong single-plate girders of the usual type, which lie underneath the rails, with cross girders and side brackets over which the platform is laid. This bridge is lifted by means of a lever 40 feet long, formed of two plate girders braced together horizontally, and attached rigidly at right angles to the centre of the bridge, and this lever is itself balanced at its centre on blunt steel knife edges like the beam of a pair of scales. The weight of the bridge at one end of the lever is counterpoised by an equal weight of metal attached to the other end, so that the whole structure turns freely on the knife edges, which work in steel pillow blocks on the top of metal standards, one on either side of the lever. The opening and closing motions are regulated by a small crab-winch and chain worked by hand; the ends of this chain are attached to the lever at several feet on either side of the knife edges, and its centre is wound on or off from the barrel of the winch, which is itself bolted down to a mass of concrete extending beneath the metal standards.

The man in charge works this arrangement with the greatest ease, and it is so regulated that the bridge is opened or closed in about one minute. It might be moved much faster than this, as the friction is reduced to a mere trifle by the knife edges, but it is not convenient to put so large a mass in rapid motion when there is nothing to be gained by so doing. It was essential that the bridge should be erected speedily and so as to interrupt the traffic as little as possible, and the first engine passed over it in about twelve weeks after the contractors, Messrs. Courtney, Stephens and Bailey, of Dublin, got instructions to proceed with the work and the traffic was interrupted for only about one week during erection. The lever sloping upwards has a somewhat singular appearance when the bridge is in position for trains to pass over and, on the other hand, the bridge itself has a singular effect when it is tilted up into the air for canal boats to pass beneath; but the author has successfully obtained what he aimed at—namely, simplicity of design, strength, ease of working, little aptitude to go out of order and last, but not least, very moderate cost.

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9. *The Irish Siren Fog Signal.* *By* J. R. WIGHAM.—See Section A, p. 437.

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10. *A New Form of Mining Lamp.* *By* DR. CHARLES BALL.

TUESDAY, AUGUST 20, 1878.

The following Papers were read:—

1. *Report of the Committee on Instruments for Measuring the Speed of Ships.*
See Reports, p. 219.

2. *Report of the Committee on the Datum Level of the Ordnance Survey.*
See Reports, p. 219.

3. *Report of the Committee on Tidal Observations in the English Channel, &c.*
See Reports, p. 217.

4. *The River Shannon: its present State, and the Means of Improving the Navigation and the Drainage. By* James Lynam.

The flood drainage of the River Shannon district has been sought for and expected during the last fifty-seven years. On April 5, 1821, the first Mr. Rennie wrote the following letter to his assistant, John Grantham:—

"London, April 5, 1821.

"Sir,—His Excellency the Lord Lieutenant of Ireland having through the Right Honourable Charles Grant directed me in his letter of November 8 last to get a survey made of the River Shannon, as to its levels between Killaloe and Roosky, with a view to lower its surface, in order that the water from the bogs lying on each side of it may be more effectually got off, I request, in the name of the Irish Government, that you will set out for that place to ascertain the practicability of carrying the above wish into execution.

"I am, Sir, &c.,

"John Rennie.

"To John Grantham, Esq."

Since 1821 three select committees of Parliament have sat inquiring into the Shannon improvement projects. Three Acts of Parliament have been passed for it. Ten engineers have been employed by the Government to plan for it; £11,000 were formerly paid for plans and reports; £557,016 were expended on works, &c., in it; £22,000 have been expended in maintaining it; £10,000 have been recently spent in inquiries about the results.

The results are: The floods do not now rise so high, nor cover so much land, nor last so long, as they formerly did; but all the good land that was formerly flooded is still flooded. The difference between the former high floods and the recent, covered generally poor margins, or gravelly and shrubby beaches.

Twenty-four thousand acres of low lands are still damaged by floods. The outlets of seventeen rivers are obstructed. Several public roads are flooded. A swamp 150 miles long is maintained. Many dwelling houses are flooded. On one occasion I counted thirteen of those flooded houses. I went into some of them. The water was a foot deep on the floors. They had the fireplaces raised over the water. They had stools and chairs as steps from the fire to the beds; they slept in their beds with 6 in. to 18 in. of water under them on the floor.

I was able to measure accurately the greatest height the flood had been by the marks it had left on legs of the tables.

Near Athlone the people abandon their houses when the floods rise high, and go into lodgings in the town. When the flood falls they go back and clean out the houses: but it sometimes happens that another flood comes and drives them out again. These great floods never occur in spring, summer, or autumn, but in December, January, or February. During spring the low lands, when not flooded, are saturated to a very injurious extent.

Near Carrick it often happens that the water is low and the lands dry in March. The farmers then put down crops in the low lands, and in April a flood may come, a small flood which rises merely to the level of the land surface for ten or twelve days, but it rots the seed. A small amount of sluice in the weir would prevent this.

These are the sad results of the expenditure of more than half a million pounds under Government control. How is this great evil to be remedied, and at what cost? This is what I am going to explain. During eighteen years, since 1860, I have been studying the subject, surveying, sounding, calculating, and writing to promote the much-needed improvement. May I hope it is now to be really forwarded?

The Shannon Commissioners reported to the Lords Commissioners of Her Majesty's Treasury, in 1850, that "It is probable that at some future period it may become necessary to make additional excavations at some comparatively confined channels of the Shannon at and below Shannon Bridge, and immediately above the weir at Meelick." These are all the works the Shannon Commissioners who knew the river so very well considered necessary to make a completely effective flood drainage of the Shannon district. They then reported, "Fortunately such works, though probably indispensable, will not be very expensive." (Eleventh Report, pages 8 and 9, March, 1850.)

A very eminent engineer employed by the Government in 1862 to 1867 made a minute engineering survey of the whole river and reported. His estimate for works is £290,000 to improve 24,000 acres, being £12 an acre English. This was for seven divisions or levels of the river. Subsequently an Act of Parliament was passed for works to drain 17,500 acres in three and a half out of the seven divisions, at a cost of £300,000, being £17 an acre English. At this rate the regulating of the whole river would cost £435,000 now, in addition to the £557,000 before, making £992,000. To many minds it must occur that this large estimate is probably founded on mistaken views of the requirements of the case.

The Lords Commissioners of Her Majesty's Treasury, by their minute dated May 21, 1866, appointed me the tenth engineer to make an engineering survey of the Shannon, and to design and estimate for all works "necessary for securing the low lands from summer and autumn floods, and from ordinary winter floods." I did so, and the Parliamentary paper I hold in my hand is my report dated April, 1867, and printed by order of the House of Commons, May 15, 1867. My estimate is £144,000 for 24,000 acres, or £6 per acre.

My object in coming before you is to prove that this smaller estimate is much nearer the truth than any of the others. I will not trouble you with any mathematical or engineering calculation. I will accomplish my object by describing and explaining the facts and circumstances of the river.

The Erne and Shannon rivers have three features which render it peculiarly easy to regulate their floods and prevent the inundations. First, they have large superficial areas of lakes; second, their channels between the lakes are wide and deep—

so capacious as to carry their floods with an inclination of less than an inch a mile; third, their floods rise slowly, 4 in. to 8 in. in twenty-four hours, very rarely a foot in twenty-four hours. The Shannon has a fourth feature very valuable. All the mill weirs and fish weirs have been purchased and removed, and all the shoals have been deepened at a cost of £557,050 7s. 6¼d. (See Eleventh Report of Commissioners, dated March, 1851.) Its rain basin contains 87,000 acres of lakes.

In the length from Battle Bridge, above Carrick-on-Shannon, to Killaloe Bridge of 118 miles,

	Miles.
The lakes occupy	50¾
„ broad, deep channels extend for	61
„ confined portions of the channel occupy merely	5

The portions of the channel so confined as to be visibly obstructions are but two, each half a mile long. Neither mill weir nor fish weir stands in the way of the current. The floods scarcely ever rise a foot in twenty-four hours. The great floods are but 3½ ft. where deepest on the land, and generally but 2 feet deep, and merely 18 inches deep over large areas. It is clearly the most easily regulated river in the world. Surely less than £400,000 might do it.

The Shannon river is accurately shown in plan on the Ordnance 1-inch map. It rises in a rather desolate valley in the Leitrim Mountains, in latitude 54 deg 14 min. 3 sec., and longitude 7 deg. 55 min. 7 sec. Its source is a circular basin locally called the "Shannon Pot," 55 feet in diameter, and about 20 feet deep. The water is a fine clear bluish colour. When I saw it, in 1875, its surface was 5 feet under the land, and the stream from it was but 3 feet wide and 2 feet deep. In wet weather it rises over the surface of the land, its centre appears to be higher than its circumference, and an immense quantity of water issues from it and rushes down 11½ miles to enter Lough Allen, which is seven miles long.

From Lough Allen to the tide of the Atlantic Ocean at Limerick, a length of 140 miles by the sinuosities of the river, the Shannon has been made navigable with a depth of 6 feet of water. It lies naturally in eight separate levels; but the lowest at Limerick is very small and detached from the others by a length of five miles and a fall of 90 feet. The upper level at the outlet from Lough Allen has a fall of 20 feet in six miles, and affords no matter for discussion here. Therefore, we will consider only the six levels from Carrick-on-Shannon down to Castle Connel.

The lowest of these levels between Castle Connel and Killaloe is but small, containing only 641 acres of low land, liable to be flooded in summer or autumn, and rarely covered with more than from 1 foot to 1½ foot of water. In twenty years they were flooded as follows: In the month of August once; in September once; in October five times. The owners have not asked for any improvement of the Shannon river, they have never joined any of the deputations, signed petitions, nor subscribed money. Would it not be very wise to leave them out of consideration? The works proposed for the upper divisions will do them some good; let them have it. The exempting of this division from a general measure of improvement will appear the more judicious when I tell you that the Government estimate for freeing the 641 acres of meadow from being flooded is £37,200, being at the rate of nearly £60 an English, or £100 an Irish acre. This would reduce the Government estimate from £300,000 to £263,000 for 16,700 acres, and reduces the cost on the lesser area from £17 an acre to 15 guineas.

The Shannon floods may be well studied in three classes—namely, small floods, great autumn floods, and great winter floods.

The small floods have occurred every year and in every month. They have kept the land saturated and cold during March, April, and May, which has prevented the growth of good grass, and promoted the growth of sedge and weeds. This herbage grows only late in the season, and is late coming to maturity. The mowing of the crop is thrown back into the rainy season, and the saving of it is laborious and expensive and often impossible. In the Shannon large flat meadows there are three qualities of hay, viz. sedge mixed with tall soft weeds, varieties of carex, lets at £2 to £3 an acre Irish; second, brown bent grass with some natural rye-grass, and great quantities of meadow sweet, lets at £4 to £5 an Irish acre; third, Timothy grass,

phleum nodosum, excellent hay for hunting horses, and lets for £6 to £8 an acre. I have dug up and examined the soils of the three qualities of meadow, and failed to discover any difference. The difference in the values of the meadows results from a difference of the levels of the lands. The Timothy grass (such good horse hay) meadow lands are 9 inches to 15 inches higher than the others, and are consequently above water a month earlier in spring, when they shine forth beautiful bright green islands. The sedgy, weedy meadows are the lowest by some inches, and are saturated longer than the others. The kindness of the soil of these is evinced in many places by the following interesting fact: on examining the surfaces closely numerous plants of clovers and some fine species of grass are to be seen, healthy, but small and distant. Of course if these lands were freed from saturation during spring, summer, and autumn, the clover and fine species of grass would flourish and extend in a material degree, and in a few years these meadows would become much increased in value.

The aggregate amount of injury to the crops from small floods in thirty years far exceeds the amount of damages that have actually occurred from the one great autumn flood that has occurred in that period.

The quantity of water flowing off in the river at Killaloe from a rain basin of 4,000 square miles, 2,560,000 acres, in all those small floods is under 300,000 cubic feet per minute. The present river channel is fully broad and deep enough to carry off that quantity and more at a moderate velocity. The only obstructions are the *weir mounds*. While all the low land for 120 miles lies scarcely flooded, but steeped in water, the weir mounds, with a fall of several feet at each, but without any sluice or flood-gate, act as permanent artificial barriers to the flow of the river. Fifty lineal feet of open sluice in each weir would relieve all the low land in the Shannon valley from saturation.

The Great Autumn Floods.—One great autumn flood has occurred in the Shannon during the last thirty years. It destroyed the whole of the crops on 16,300 acres, and injured 3,000 acres more. It began to go out on the ground at Portumna on August 13, 1861, and rose 1 foot 3 inches in five days. It remained at that height for five days more, when it began to fall. The very lowest lots of land were covered with water 1 foot 9 inches deep. The large areas of meadow were covered merely 1 foot 6 inches deep. The flood began to fall on August 24, and continued to fall at the average rate of an inch a day till September 9, then there was no water on the meadows, and so it remained till September 23, fifteen days; but the water in the river and the drains was even with the surface of the land. In working at the hay, men's feet sank into the ground. The muddy water rose after them. The hay lay there under the owners' eyes rotting, scarcely covered, but wholly saturated, for fourteen days. There was during all that time a fall of 3 feet over the Killaloe weir mound.

It is important to note well here two things—how slowly the flood rose on the land, merely 22 inches in six days, or $3\frac{2}{3}$ inches average in twenty-four hours; second, what a small depth of flood water there was on the land, viz., 19 inches depth of water for five days, 13 inches depth for ten days, 10 inches depth of water for twelve days. Saturation merely then for fifteen days more up till September 24, yet it rotted the whole crop; but it must be easy to prevent such small inundation.

Another very important fact to note; there is no obstruction whatever in the Shannon at or near Portumna to prevent the free flow of its flood waters into Lough Derg, which is a wide and deep lake of 30,000 acres, $22\frac{1}{2}$ miles long. This wide deep water, having no appreciable fall in the surface, goes to within 800 feet of the great weir mound at Killaloe. This channel for 800 feet length is 470 feet wide, with 8 feet depth of running water, and an inclination of $1\frac{1}{2}$ foot per mile down to the weir. Over the weir mound there is a sudden fall of the water of 2 feet 2 inches.

This diagram section annexed represents accurately the relative levels and inclinations of that flood above, at, and below Killaloe weir. It is drawn from levels taken by myself there with a spirit level in August, 1861, when that flood was at its highest.

There was, as measured by me in the height of that greatest of autumn floods, on August 21, 1861, a cataract, a clear fall of 2 feet 2 inches over the weir. The

river channel thence downwards to Killaloe Bridge was more than 470 feet wide by 6½ feet deep, with a surface inclination of 3½ feet per mile. From the bridge downwards there is a fall of 4 feet in one-quarter of a mile, as shown on the diagram section.

I ask, Was not that weir mound on that occasion a great obstruction? Evidently it was.

If that weir mound had not been there on that occasion, where would have been the levels of the flood surface from its site upwards to Portumna and Meelick? I submit for your consideration that they would have been as I now point out on the diagram.

Let a line be drawn from the surface of the water just below the weir, upwards to the broad deep water, and parallel to the surface of the flood river, as it was on August 21. Had the weir not been there the water a few feet above the site of the weir would have been a fraction of an inch higher than that line, and 800 feet upwards, which is above the head of the shoal, and in Lough Derg the surface of the flood water would have been 6 inches above that line.

The flood water would be running in a channel 6 feet deep instead of 8 feet deep, and must run faster, and must have a greater inclination. The velocity in the 8 feet deep channel was 281 feet; in the 6 feet channel it would be 375 feet per minute.

An increase of 6 inches in the surface fall from the broad deep water to the site of the supposed removed weir mound would suffice to increase the velocity so as to carry off the same quantity of flood water in the same time with 2 feet less depth as required. Of the 2 feet 2 inches that would be gained just above the site of the supposed removed weir, 6 inches would be lost in generating the required greater velocity for the shallowed channel, and 20 inches would be gained in Lough Derg; and by that lough the same would be gained at Portumna, that is, the flood water would be 20 inches lower, while the meadows were covered only by 20 inches of flood water, and that for merely five days. Therefore, if the weir mound had not been at Killaloe in August, 1861, the low lands above it at Portumna would not have been covered at all by flood water. They would have been merely saturated. Instead of being flooded for twenty-seven days, the lands would have been merely saturated for ten days, and thenceforward all the lands would have been quite dry for twenty-eight days, and the crops might have been saved.

If the Killaloe weir mound were removed and replaced by a movable regulating weir, another important element would come into favourable action. The immense capacity of Lough Derg as a storage reservoir, hitherto valueless, would be utilised. The lake contains 30,000 acres = 1,306,800,000 square feet. The proper level for steamboat navigation proposed and recommended by the Shannon Commissioners and legalised by the Shannon Act is 2½ feet under the surface of the meadow land. The capacity of that reservoir is 3,200 millions cubic feet. When the great rainfall occurred on August 13, none of it was available. It had been filled up gradually during the previous month by ordinary wet weather and small floods. It might have been all available that time to store an immense quantity of flood water, while the rest would be flowing off gradually to the sea. The quantity of water in the river during the previous month was under 400,000 cubic feet per minute. The channel was fully capable of carrying off that quantity at the legal navigation level, and keeping the surface of the Shannon river and of Lough Derg down to the legal 2½ feet under the surface of the low land. Had it been so, the rise of 21 inches caused by the rainfall of August would have left that water surface, when highest, some inches under the low lands.

Fifty wholly removable regulating weirs were constructed in the Seine several years ago. When quite closed up in summer they maintain the required depth of water for an immense steamboat navigation. When wholly open in floods there is no fall in the river surface. They occupy no part of the natural fall of the river surface. A remarkable one of these has been in excellent action for several years at a place called Port-à-l'Anglais, above Paris, and above the junction of the Seine and Marne. I saw it when all open. There was not a ripple on the river flowing by. I saw it raised and lowered with ease and facility. I have here a letter from M. Cambuzat, the chief engineer of the River Seine, in which he informs me that all those wholly removable regulating weirs in the Seine are remarkably effective and suitable for regulating that great commercial river.

Let me now put forward the following proposition:

If, in July, 1861, a month previous to the great flood, the Killaloe weir mound had been wholly removed, and a removable weir constructed at a proper level, and subsequently properly manœuvred, during the month of August none of the crops in the level of the Shannon above that weir would have been materially injured.

No other flood of so great a quantity of water as that of August, 1861, has occurred during the last thirty years. It has been estimated to be 900,000 cubic feet per minute from a rain basin of 2,600,000 acres, being one-third cubic foot of flood water from each acre of land per minute.

To prevent all floods of that magnitude—all summer and harvest floods from going *on* these lands—all that is necessary is, to make a channel that will let off that quantity of water at a level of 1 foot 9 inches lower than it was in August, 1861. The removal of the weir mound and constructing a movable weir would accomplish that.

To have the crops quite safe from *saturation* the flood should pass off at a foot lower level. That must be done by excavation 210 feet wide, 3 feet deep, and 2,400 feet long: 56,000 cubic yards, at 4*s.* = £11,200, will accomplish that.

The Navigation.—From Limerick to Portumna, Meelick, Banagher, and Shannon Harbour at the junction of the Grand Canal from Dublin, there was a good navigation before the Shannon works were planned. There was a large trade, and many passengers travelled in the steamboats. I was myself a passenger many times, and a very pleasant passage it was.

The parties then using the navigation were the Grand Canal Company and the City of Dublin Steam Packet Company. When the Shannon improvement project went before a Select Committee of the House of Commons those parties were represented by the Chairman of the Canal Company and the Manager of the Steam Packet Company, Charles Wye Williams. They gave very strong evidence that the boats then on those waters were sufficient, and that great new locks and canals were not necessary. The Commissioners thinking they knew what was wanted better than the navigation companies, built new canals and locks at great expense.*

The results are: The state of the navigation at Killaloe and Meelick is now a little better in summer and low-water times than it was before. But in floods it is worse at Killaloe, and at Meelick in the new sailing channel. In high floods at Meelick the current is too strong for the steamboats in the new channel; they cannot go against it, they go up through the old canal and the old lock. Of course where they go up with ease they may come down. Therefore the great new lock may be left unused during floods. Therefore the great weir mound by it is then doing no good for navigation. It might be all out of the river during floods. Therefore a movable weir there open more or less to keep sufficient depth of water in the old canal would cause no injury to the navigation. It might be wholly shut in summer without injuring the land. The weir mound stops 5 feet of water in floods. Of course if these 5 feet of fall were distributed along the surface of the river, the velocity would be increased and more water would pass off much quicker.

The Killaloe Rapid.—At Killaloe the old navigation channel was a canal, protected from the rapid river by a strong permanent embankment, which was one of the public walks there.

The Commissioners cut away a large portion of that embankment, and let the river run into and along the old canal, which made it a very dangerous rapid in mid floods, and in high floods it stops the navigation for weeks. No steamboat could go against it, nor with it.

I saw steamboats going up it with several men and horses hauling in aid of the steam power.

In going down the boats go stern first, with cables from the stem to great posts which the Commissioners fixed in the bank. One rope is wrapped round a post, eased off to let the boat go down opposite another post, round which another rope is wrapped, and so on.

I have read in the annual reports of the Canal Company's directors that the

* See evidence reported by Select Committee of the House of Commons. Printed by order of Parliament, July 29, 1834. Questions 409, 419, 422, 423.

navigation at Killaloe was stopped by the floods for an unusually long time that season. Such has been the state of the Shannon navigation during the last thirty years.

Improvement of the Navigation.—The necessary works for improving this navigation are:—To replace the protecting embankment at Killaloe by a concrete wall. Fortunately they did not cut it all away. A length of 800 feet is enough to build. When that wall would be built the proposed movable weir could be operated without injury to navigation. It would be well to dredge a foot deep of dredgable clay from Derry Shoal and White's Ford. A jetty 20 feet wide might be built at the pier head. The Meelick Canal, two miles long, should be cleaned. The obnoxious corner called the Devil's Elbow above the canal should be cut off. These are all that are required for the navigation in order to improve the drainage.

Upwards to Athlone and Carrick-on-Shannon, the state of the navigation is quite good enough; but it is almost wholly useless for want of trade above Athlone. The tolls received at the eight landing quays amount to but £100 a year, which is £12 10*s*. a year to pay each lock-keeper or receiver. The four weir mounds there are firmly maintained for the destruction of crops, and the disgrace of the governing power. Is it an enemy who maintains them so?

The Storage Capacity of the Lakes.—Taking the area in square feet of the Shannon lakes, and the depth in feet of the legal navigation level under the surface of the land, there results 6,000,000,000 cubic feet. If at the beginning of great rain-falls the lakes were all down to the navigation level, which they will be with removable weirs, there would be a storage reservoir of 6,000,000,000 cubic feet. This would store 300,000 cubic feet of flood water per minute for fifteen days, while the rest would be passing off to the sea through the open weirs.

The greatest autumn flood lasted but seven days, and then fell regularly for and remained low for twenty-six days. The lakes would store 500,000 cubic feet per minute for eight days. Would these storage reservoirs have failed just when wanted on that very important occasion? Surely not.

The Injurious Effects of the Weir Mounds.—In ordinary wet weather, during all seasons, they keep the water so high as to saturate the lands, which is a great evil to the crops and to the agricultural and sanitary state of the country. In medium wet weather, as no opening can be made to let off ordinary surplus water, they cause the lakes to be filled to the brim, which is 2½ feet over the legal navigation level. When that occurs there is a natural fall from Carrick-on-Shannon Bridge to Killaloe Bridge of 37 feet, and out of that 37 feet no less than 21 feet fall are wasted by the weir mounds, leaving only 16 feet fall in the surface of the river to propel the stream. In the highest autumn floods 16 feet are so wasted.*

Mitchell Henry, M.P. for Galway, and I boated over many miles of meadows where the hay lay, part in grass, cocks half covered, part in swarths wholly covered, between Athlone and Meelick. When we got to Meelick there was a cataract over the weir mound of 5 feet. There was but 1 foot to 2 feet of flood water rotting the hay.

If in planning for the improvement of the drainage of a river we begin by robbing the surface of the stream of half of its natural fall, of course we must estimate for very large excavations. Take, again, the channel at Killaloe as an instance. The natural actual fall there in great autumn floods will be from the deep wide water of Lough Derg down to the bridge 1 foot 3 inches in 2000 feet, or 3¼ feet per mile. The present channel is 470 feet wide, and with this fall and a depth of 6 feet of running river it would as it is carry off 900,000 cubic feet of flood water at a level that would keep Lough Derg and the river at Portumna under the low lands.

Now I beg your careful attention to a fact. The Government engineer, after building the protection wall which would protect the navigation channel from the river, proposes to construct a weir across the river that will of itself occupy 2 feet of the natural fall, and deprive the river surface of it. Of course he must

* See Report to the Lords of the Treasury, by J. Lynam, C.E., printed by order of the House of Commons, May 15, 1867.

estimate for a very large quantity of excavation to make a sufficient channel with only the remainder of the fall, so he does.

		£
177,778 cubic yards of rock at 3*s*.	... ...	29,900
60,000 " " clay at 1*s*.	... ...	3,000
237,778 " "	... ...	32,900

One more curious fact is the place he excavates the rock; that mass of rock on the side of the river which is 20 feet over the river. There he has to excavate hard rock 20 feet deep before getting to the river surface; he then cuts down 6 feet deep in the river: he cuts 26 feet of hard rock to get 6 feet of new waterway to carry off 6 feet of water. Six feet excavated from the *bed* of the river will increase the waterway to carry off as much water as 26 feet excavation on the high side, and it may be done for less cost per foot, because the bed on the other side is not rock. Below the weir it is dry in dry summers, and may be easily made dry in any summer. Above the weir may be dredged. Is this good river engineering? It is an example of his principle all the way up the Shannon. His proposed weirs at Killaloe, Meelick, Athlone, Tarmon, Roosky, Jamestown, each occupy during floods 2 feet or 2 feet 2 inches of fall, thus taking from the river surface nearly half its natural fall. He has acted on mistaken principles in other points, which, added to those explained, have made him estimate for three times more excavation, particularly in rock, than is necessary.

The estimate of 1867 for the whole river is £290,600. The sum which the Government estimates for works in three and a half out of the seven divisions of the Shannon is £300,000, which is one-half added to the estimate of 1867. At this rate this revised estimate for the seven divisions would be £426,000. I submit for consideration the following propositions:—

1. The circumstances of the Shannon render it very easy to regulate its waters and prevent injurious floods.

2. The navigation and the drainage of the Shannon district may be improved to the full extent necessary or desired for a third part of the sum which the Government has been advised to insist on as necessary. This may be effected by means of simple and safe removable regulating weirs, which may be all built in one season, and by dynamite blasting and steam dredging.

I have all the details to prove this for each division of the river. I have minute accurate large scale maps, sections, and cross-sections of every strait and shoal, with the *régime* tabulated for the present and for the proposed state of the river in floods.

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5. *On the Present State of Electric Lighting.* *By* James N. Shoolbred, *B.A., M. Inst. C.E.*

Electric lighting has only attained to its present development by certain marked stages of progress.

Though the electric light was first produced at the commencement of the century as a chemical experiment, yet its first stage of practical application did not take place till towards 1849, when, on the recommendation of Professor Nollet of Brussels, the large cumbrous magneto-electric machines of Holmes of London, and of the Alliance Company of Paris, were constructed to produce a current alternating in direction for the supply of a single light of considerable intensity. Machines of this kind were erected at the South Foreland Lighthouse in this country, in France at those of Cape Grisnez and of Cape La Hève, and at a few other lighthouses in the North of Europe. With these exceptions, these machines may now be considered as obsolete

The next stage of progress in electric machines was the result of the important discovery in 1867, almost simultaneously by Sir Charles Wheatstone, Dr. Siemens, and by Mr. S. R. Varley, of the principle of "reaction" between the currents created by the rotation of one electro-magnet in front of another fixed one, whereby,

these currents, on being passed backwards and forwards between them, are gradually augmented to a very considerable degree, the result being a small, economical, and much more powerful machine, termed "dynamo-electric" (electro magnets being used) than are the previously described "magneto-electric" ones (where permanent magnets were employed). The best known machines of this class are the "Siemens" and the "Gramme" in this country, and in the United States the "Brush" and the "Wallace-Farmer."

The third and present stage of electric lighting is that of the divisibility of the light, *i e.*, the production of a number of lights from one machine. This has been effected in practical use by Lontin with his double-machine, and the double-Gramme feeding the well-known Jablochkoff candles. With these last, an Alliance machine was at first used, but latterly M. Gramme devised his second machine, and which has the appearance of the already existing Lontin.

In the double machine (of Lontin, and also in that of Gramme), the current is created in a small one, termed the "generating" one, and passed on in one continuous direction current to the larger or "dividing" one; on the outer envelope of which it is received divided into a number of distinct circuits, which may be coupled together at will. The Lontin machines, so far, have produced twelve circuits from such a machine with a maximum, in lengthened use, of thirty lights; while the Gramme generally works with four circuits and feeds sixteen Jablochkoff candles.

Of the lamps or regulators, those most in use for single lights are the Serrin and the Siemens; while, where many lights are produced, the Jablochkoff "candles" and the divers forms of Lontin regulators are available The Jablochkoff candle consists of the two carbons placed vertically side by side, with an insulating layer of plaster of Paris between them: which is an attempt to dispense with the delicate mechanism of the regulating apparatus, and attended with only very moderate success. The arrangements of the Lontin regulators are very ingenious, and very sensitive; some of the forms may be placed in any position whatever and be used with currents, either continuous or alternating in direction.

The very careful preparation of the carbon-sticks between which the electric light is produced is at present receiving attention, so as to render their composition as homogeneous as possible, and thereby to reduce the flickerings in the light produced.

The motor power to cause the necessary rate of motion to the revolving electro-magnet or induction coil (generally between 400 and 1000 revolutions per minute) may be either hydraulic power in the form of a turbine or otherwise, or a gas engine, or a steam-engine. But, whichever of the three is used, extreme regularity of motion is an absolute necessity; otherwise any want of steadiness in running is productive of flickering in the electric light. Therefore, where possible, the engine performing this duty should be special for the purpose, and not have other work to do at the same time.

A most important consideration in connection with electric lighting is, apart from the prime cost of the machines, motor, lamps, &c., the amount of the working expenses thereof, and chiefly the proportion and cost of the motor power to the amount of light produced. A rough estimate of this is given by the designers of these machines as one indicated horse power for each light of 1000 standard candles. Where the number of lights is considerable, this may hold good; but for a few, or for single lights, a larger allowance for engine power should be made, even when running ordinarily, and without the sudden and severe strains to which they are exposed. Many manufacturers at and near Paris, at Rouen, and at other places in France, have made use of electric lighting in spinning and weaving sheds, in iron works, &c., for the last two years, and they generally consider that they have been supplied with a vastly augmented amount of illumination at considerably less than one-half the cost of the previous, and much poorer one, by means of gas

Though electricity may replace gas lighting to some extent in the illumination of large areas, and in certain manufactures, yet it cannot pretend to trench upon the special, and the most extensive field for the use of gas, the lighting of private

houses, until some permanent indestructible light-producing points very different from the present carbon sticks be discovered.

Nor should the sanitary advantages of electric illumination in buildings over that by gas be overlooked.

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6. *On a Process for Cutting through Sand-bars in Rivers and Harbour Entrances. By* C. Bergeron, *C.E.*

The process requires the prolongation of one of the piers or jetties at the end of which the sand-bar is formed. The new pier is to be made on iron piles, in the same style as the numerous jetties or piers at watering places, such as Brighton, Southport, Llandudno, &c. They offer no resistance either to the waves or to the currents of the sea.

The pier is to support a pipe of 8 or 10 inches diameter, into which water, coming from pumping-engines on the shore, is forced at a pressure of 10, 20, 40, even 50 atmospheres. The pressure is in proportion of the resistance of the sand or shingle of which the bar is formed.

At every forty metres there is a branch pipe which carries down the water to another pipe of the same length of forty metres. This pipe is to be put horizontally between the piles of the pier and supported by them.

That horizontal pipe, which is at the level of the water at low tide, and which it is easy to reach every fortnight at the epoch of spring tides, has twenty outlets of one inch diameter at two feet distance from each other.

India-rubber flexible pipes of a sufficient length are tied to those twenty outlets; they are exactly like fire-engine hose; they are tied two and two to a plank lying at the bottom, which forces the jet of water to strike the sand at a convenient acute angle.

The jetties are prolonged as far as the total length or width of the sand-bar.

When the cross-section of the sand-bar has been properly measured, the highest parts, which correspond to a certain section of the feeding pipe on the jetty, are removed by the jets of water of that section, working only during a few minutes.

Every sectional pipe is connected with the main feeding longitudinal pipe by means of a valve. It is only four inches in side diameter, which is quite sufficient to feed twenty india-rubber flexible pipes of four-fifths of an inch diameter. The valves are to be opened one after the other.

The operation of cutting the sand-bar must take place at the moment of high tide, when the tide begins to recede. It is at that moment that the current of the flood tide is most rapid, and when all the water accumulated in the harbours or rivers begins to run into the sea. At that moment, all the sand removed by the jets of water is carried away. A very large ditch or furrow is formed at the end of the jets of water, and ships are no longer prevented entering the harbour.

WEDNESDAY, AUGUST 21, 1878.

The following Papers were read:—

1. *On the Use of Wind Power for Raising Water, Disposal of Sewage, and Drainage, with special reference to Ireland. By* JAMES PRICE, *M. Inst. C.E., M.A.I.*

The power of the wind, though so immense, as shown by its action on the surface of the ocean, and by its effects in conveying such an enormous weight of water in the form of rain clouds at so great a velocity, is yet but sparingly used by mankind: still it always has been, and will be, used at sea for ships, and saves an immeasurable quantity of coal which would be otherwise expended if steam entirely replaced sails.

The crude wind power measured for a height of 70 feet constantly acting over Ireland amounts to 360 millions of horse power. The convenience of steam power has led to the disregard of the common forces of nature. Wind power being almost without limit, it becomes unnecessary to complicate the machine for utilising, it so as to save waste, as in the case of water power; the only necessity being to have the fans or sails self-adjustable, according to the force of the wind to guard against injury by storms.

Wind power is not suitable for constant work except as an assistant to steam to save fuel, taken alone it is adapted to intermittent work, only such as—

1. Water supplies for small towns.
2. Disposal of sewage in rural districts.
3. Drainage of marshes and peat bogs.

1. Deep springs are generally easily found in the neighbourhood of small towns, affording sufficient supply. Conducting water from a distance may in some cases be too costly, whereas a wind engine of 20 feet in diameter with proper pumps, costing not more than £200, might be relied upon for supplying a town of 1000 inhabitants with water at high pressure, even allowing for considerable cessation of wind; fair-sized reservoirs being necessary to provide for calms; or else arrangements for using animal power.

2. The infiltration process to purify sewage is advocated by the author; to be applied by pumping out the under water of porous ground, and thus causing the liquid part of the sewage deposited on the surface to soak down, and be pumped out after having passed through a great thickness of earth. To carry this out, it is proposed to form an annular cesspool with porous bottom, with a deep well sunk in the middle of the island to be kept constantly pumped out by wind power, the surface sludge being occasionally removed by scraping, new clay being substituted. Long calms would not affect this process, as the cone of earth once dried would hold a vast quantity of liquid before being saturated; from experiments of the author, say from 30 to 40 per cent. of bulk of earth.

3. The advantages of drainage in Ireland are much greater than the value of the land saved from floods. The climate of Ireland would be improved; its chief defect is a want of summer heat, which is from 2° to 3° lower than it ought to be, as the swamps and grass lands act as the envelope of a wet-bulb thermometer, which on an average of two summers was found by the author to reduce the temperature of the mercury 3°·68.

The undrained land in the basins of the River Shannon and River Erne, containing 5,000,000 acres, very much affect the heat required for ripening of cereals; a few degrees in the British Isles being of vast importance, as the average

summer temperature is about 58°, which is just the lowest at which cereals will ripen. For draining bogs wind power is specially applicable, from the fact that the bog, once dried, becomes like a dry sponge; so that if wind ceased even for weeks, the surface waters would not appear, but be at once absorbed; as to drainage by pumping, even when steam is used, the cost is not formidable. Mr. J. Woodward Stanford owns a property of 2200 acres of slob land south of Wexford Harbour, now drained by steam power, averaging one horse power for every 244 acres. It may be safely taken, allowing for intermittent work, that a one horse power wind engine would drain 100 acres from the natural rainfall. There are numerous sites for wind engines in Ireland, the interior being flat and free from trees; the velocity of the wind is high, averaging fourteen miles per hour.

Very portable wind engines and others of large dimensions, having all necessary improvements, are manufactured by Messrs. John Warner and Sons, of Crescent Foundry, Cripplegate, who also furnish all pumps and appliances for raising water, their noria or chain of tumbling buckets being very suitable for drainage; also their Archimedean screw suits wind-power well. American wind engines of very simple construction were exhibited by Messrs. McKenzie and Sons, of Dawson Street, in Dublin, at the last Agricultural Show held in this city; they were made by the United States Wind-engine and Pump Company of Batavia, Illinois. These range from 8 to 60 feet in diameter, and are of an annular form, somewhat like Messrs. Warner's; they are much used in America for farm purposes and lifting water.

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2. *A System of Ventilation by Means of Fans and Punkahs worked by Compressed Air for use in Hospitals and Barracks in India and other Tropical Climates. By the* Hon. R. C. Parsons.

Many here are no doubt aware how extensively the punkah is used in India, and that among the European inhabitants it is characterised as essential to the preservation of health. The form of punkah which (especially among the medical authorities) is considered the most effective is that known as the "Pole Punkah." This consists of a heavy wooden pole about 10 feet long from which a curtain of coarse canvas covered with calico is attached. This pole, with its curtain, which is about three feet deep, is then suspended from the ceiling of the apartment in which it is required, and it is ready for use.

In the case of hospital wards the punkahs are generally worked in sets of from four to six in a row placed parallel to each other. The coolie whose duty it is to pull the set of punkahs is placed at the end of the row, and by means of light cords which attach the punkahs to each other keeps up a swinging motion throughout the line.

Working in spells of two hours at a time, two or three relays of coolies maintain more or less a constant swinging in a set of punkahs throughout the hot season, which, on an average, extends from the months of March to October inclusive.

But the great difficulty which has always been experienced is the very natural offence of the coolie going to sleep at night, when most needed. The great evils arising from this offence are the chills which are produced by an intermittent action of the punkahs, which, after they have been repeated upon Europeans several times, frequently terminate in attacks of fever.

The cooling action of the punkah depends entirely upon the agitation of the air in its vicinity, and also, as a matter of course, upon the evaporation of the perspiration from the bodies of the human beings situated near it; consequently its cooling action ceases whenever the surrounding air is charged with moisture, which is often the case at particular seasons. In order that the punkah shall produce its full effect, it is absolutely necessary that the pole from which the curtain hangs shall receive a sudden jerk at the commencement of the swing, so as to raise the curtain more or less into a horizontal position; the punkah should then move on to the end of its swing at a regular speed, during which time the curtain flaps

downwards, carrying with it a current of air which strikes the persons seated beneath it.

This flap of the curtain with punkahs pulled by coolies is only produced on the forward swing, and consequently the backward swing is almost devoid of cooling effect.

Having briefly sketched the punkah system as at present carried out in India, the author proceeds to indicate how, in course of time, it may be replaced by machinery. The system which the author proposes to describe is that which has been advocated for some years by Captain Palliser.

In this system the coolie is replaced by a small machine actuated by compressed air.

The machine is attached to the wall of the room in which a row of punkahs are required, and connected to them by means of light bamboo canes.

Immediately upon the compressed air being admitted to the machine, the punkahs begin to oscillate, and a jerk is imparted to them both on the forward and backward swing.*

In this system, as applied to large barracks, cantonments, or other large buildings in India, the air is to be compressed at a central station by means of a steam-engine, and transmitted through cast-iron pipes to the various buildings where punkahs are required.

The author now proposes to pass on to consider a few points connected with the proper ventilation of buildings in hot climates.

In hot climates where there happens to be no breeze and a broiling sun, the temperature of the houses becomes the same as that of the external air, and when this is the case the air within becomes exceedingly foul, in consequence of no circulation being maintained.

In order to remedy this defect, fans, termed in India "Thermantidotes," are worked at the present time by coolies. These fans, which are generally situated within the houses, draw in the external air through mats made of "Khus Khus," called in India "Tattees." The great disadvantage of the "Thermantidote" is the chilling draught which it very often produces.

After much consultation with Captain Palliser the author has designed a ventilator which is also actuated by compressed air, and which is intended to be placed in the ceilings of buildings where a thorough system of ventilation is required, whether in India or other countries where the climate is more temperate.

This ventilator consists of a fan revolving on a vertical axis. Attached to this axis is a small engine of very peculiar construction, into which is admitted high-pressure air, similar to that used for working the punkah machines. Immediately upon the air being admitted, the ventilator begins to rotate, and the foul air is removed from the ceiling where it had collected.

This system of ventilation is similar in principle to that now in use in the Houses of Parliament in London, where no expense has been spared to ensure success.

This last system of ventilation which the author has described could be applied with much advantage to buildings such as law and police courts, where the atmosphere is usually exceedingly unpleasant.

The author has carefully gone into the cost of working punkahs by the method already explained, and it seems perfectly clear to him that, where a system similar to that already described is carried out upon a tolerably large scale, it will prove a decided financial success.

This question is a very important one, both in a sanitary, and also in a financial point of view to the Indian Government, inasmuch as last year it cost them £47,000 in coolie hire to supply the hospitals and barracks with punkah power.

The author is glad to be able to state that the Indian Government are fully alive to the importance of the question, and have recommended a trial of the above system to the Government in India.*

* For a full description of the machine employed, and of the details of the pneumatic punkah system, *vide* pamphlet by the Hon. R. C. Parsons, published by Messrs. E. & F. N. Spon, London.

3. *On the Dublin Waterworks.* *By* PARKE NEVILLE.

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4. *The Design and Use of Boilers.** *By* F. J. ROWAN, *M. Inst. M.E.*

The close relation between the engineer and the physical philosopher, though obvious and often pointed out, has not been fully admitted. Yet the fact necessitates the possession of accurate scientific knowledge in dealing with engineering problems, and none demands it more strenuously than does that of the designing and working steam boilers, and especially marine boilers, for various reasons. The proper generation of steam and circulation of heated water and gases are now attracting more general attention than hitherto, and this is hopeful, because attention to principles of thermo-dynamics has led to vast improvement in the steam-engine. On these principles we must decide what is the best pressure of steam to work with, and then we must study scientifically the characteristics of a good boiler.

Professor Osborne Reynolds's table of pressures of steam in relation to economy and development of power is quoted, and also one compiled from Regnault and other authorities to show the weight of water raised from 0° C. to the state of vapour at various temperatures by 1 lb. carbon.

It being proved that high pressures of steam, say 150 to 200 lbs. per square inch, are most economical, we need to find in a good boiler—

1. The most economical and efficient means of generating steam of that pressure.
2. Strength to carry it with safety under all the exigencies of practical working.
3. Facility of construction and repair.

1. Under the first head (*a*) combustion is first considered, and the theoretical effect of the perfect combustion of 1 lb. carbon being known, we have a standard to go by.

But varying qualities of coal and unvarying defects in the mode of mixing the coal and air produce bad results.

Suction draught by jet blast is no real improvement. Mechanical stoking meets imperfectly—more or less—only one evil; and a combination of mechanical stoking with forced combustion, or combustion under pressure, is needed for all the difficulties of the case.

A plan which the author proposes is illustrated and described.

(*b*) Circulation of the heated gases necessarily comes in as an important element under this head. The elements of quality of heating surface and time of contact require to be taken into consideration, and show that the speed of travel of the hot gases must be under control; while surface is valuable in proportion as it can deal with the heat brought to it by quickly transmitting it to a medium which will convey it away.

The plan of turning the gases *downwards* before they escape to the funnel practised by the author's late father, in conjunction with the plan of forcing in the products of combustion just proposed, allows the time of contact to be quite under control, and only the heaviest, *i.e.*, the coolest, gases escape—not the hottest first, as in up-draught arrangements. An interesting instance of saving in heat by giving gases a downward current is quoted in a note.

(*c*) Heating surface is then considered; and the laws of thermal conductivity are referred to. Formulæ by Wiedmann and Franz, and by Clerk Maxwell, expressing the quantity of heat which can be passed through the metal of boilers in a given time, are quoted; and also the results of Angstrom's investigations of the same subject. These show that the relative values of different kinds of heating surface must be determined by the facility of access which they afford to the heated gases on the one hand and to fresh portions of the water on the other, and not by any arbitrary rule as to their being in a horizontal or vertical position.

(*d*) Circulation of water thus appears as one of the most important, though it is one of the most generally neglected points in boiler design and working.

The specific heat of water and that of steam being so different, it is necessary to

* Published by E & F. N. Spon, London.

have a proper supply of the former to the surfaces through which the heat of combustion is passed. The fallacy of making steam by "foaming" or "vapour circulation" for boilers is pointed out, and Mr. C. Wye Williams's table of the relative effects of water, steam, and air in contact with the plates of a boiler which are heated, is quoted.

The natural action of circulation in boiling is well known to consist, first, in the directly upward motion of the heated portions of water, and the vertical escape of the steam, and second, in the colder portions of the water seeking the coolest means of descent, when possible, undisturbed by opposing currents.

A correctly designed boiler will provide for the free action of these simple principles, which are contravened more or less by boilers of the ordinary marine type, and by all those having horizontal or horizontally inclined water tubes, of which several examples are named. None but a boiler of vertical water tube design satisfies indispensable conditions.

2. The form of the boiler introduces the question of strength, in which there are two important factors, viz. (*a*) the best form for resisting pressure, and (*b*) equal distribution of the strains due to expansion by heat. (*a*) High pressures demand diminished areas, with of course an absence of flat or large-rending surfaces or large diameters, and thus boilers of water tube design are required. Boilers of ordinary marine type, which have large external diameters, also are defective in exposing large surfaces to loss of heat by radiation, and so increasing the strains caused by unequal expansion. (*b*) The force exerted by expansion is considerable, and is enough to prove that the even distribution of heat by proper circulation and design has a large influence upon the strength and wear of boilers. Cases of boilers which suffered damage from expansion unequally distributed are quoted, and the author refers to various measurements of this force given by Professor W. Allen Miller ('Chem. Phys.,' 4th ed., p. 261), and by J. Milton ('Strength of Boilers,' Proc. I.N.A.)

3. In considering facility of construction and repair, the author refers to the drawings illustrating his paper, and recapitulates the defective points of various designs, which have come up in the preceding remarks, and he contends for simple operations in making, and for the minimum of different kinds of parts composing a boiler.

It is being generally understood and admitted that boilers ought to be worked exclusively with fresh water, and with precautions against corrosion such as are suggested in the Report of the Admiralty Committee on Boilers or in the author's paper on 'Boiler Corrosion' (British Assoc., September, 1876), it becomes unnecessary to provide for access to all the internal parts. Facility of removal of parts for repair is therefore all that is necessary under these circumstances.

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5. *On the System of Dredging usually employed in the United States. By* Robert Briggs.

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6. *On a New Ship-raising Machine. By* Thomas A. Dillon.

An oval-shaped floating canvas mattress larger and wider than the ship to be raised, and having a deep curtain of strongly netted and roped canvas brailed up all round, is lowered fore and aft over the wreck, when masts are supposed to have been cut way, down below low water as far as convenient. The canvas curtain, well weighted and chained, is by suitable means allowed to fall so that when it reaches the bottom the ship lies in the centre of an oval bell-tent. An ordinary suction pump is put in action at first; the result is that the vacuum created in the upper portion of the bell-tent induces the water on the bottom to try and fill it. This it cannot do: it merely compels the bottom of the tent or flexible diving-bell to grasp the wreck. A running rope or wire cable running string which had been rove round the mouth of the bag is hauled taut.

The suction pump now ceases, and the air pump is worked. The water is driven out of the bell by air pressure, and when an amount of water equal to the weight of the ship is expelled, the ship rises in the grasp of this octopus.

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[*An asterisk* (*) *signifies that no abstract of the communication is given.*]

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PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at £1.*

CONTENTS:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Economy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines;—Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the Recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves;—L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, the Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s*.

CONTENTS:—Seventh Report of a Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lieut.-Col. Sabine, on some Points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s*.

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck, on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—Dr. J. Percy, Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s*.

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water:—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our Knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Aryan and Aboriginal

Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at 9s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn, on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eight Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lieut.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at 10s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at 15s.* (Out of Print.)

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840, to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution

and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published* at 16*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water, and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850, to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at* 15*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851-52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852-53;—James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and

Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations; —Dr. John P. Bell, Observations on the Character and Measurements of Degradation of the Yorkshire Coast;—First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration; —Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18s.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued);—Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54; —Second Report of the Committee on the Physical Character of the Moon's Surface; —W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15s.

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55;—Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18s.

CONTENTS:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of

North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage, and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena, Part 1;—Dr. T. Wright, on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at* 15*s.*

CONTENTS:—A. Cayley, Report on the recent progress of Theoretical Dynamics;—Sixteenth and Final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mimes in Cornwall;—Dr. G. Plarr, de quelques Transformations de la Somme $\Sigma_0^{t^{-a}} \frac{a^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$ a étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $a^{t|+1}$ désignant le produit des facteurs $a\ (a+1)\ (a+2)$ &c.... $(a+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the Extent to which Mercantile Steam Transport Economy is effected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—Dr. John P. Hodges, on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain:—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856-57:—C. Vignoles, on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Prof. W. A. Miller, on Electro-Chemistry;—John Simpson, Results of Thermometrical Observations made at the *Plover's* Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852-54;—Charles James Hargreave, on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Prof. James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn, on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, Evidences of Lunar Influence on Temperature:—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, the Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at* 20*s*.

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857, 1858;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connel and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857–58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles' Paper "On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;"—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at* 15*s*.

CONTENTS:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to Cultivated Crops;—A. Thomson, of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahagow, Lanarkshire;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Breaks for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858–59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858–59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c., &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren De La Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.:—W. Fairbairn, The Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air:—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Professor H. J. Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship Performance;

—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at* 15*s*.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1859-60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Prof. Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II.;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena;—Second Report of the Committee on Steamship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

Together with the Transactions of the Sections, Lord Wrottesley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors;—Dr. E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners, Part I.;—Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships;—Warren De La Rue, Report on the Progress of Celestial Photography since the Aberdeen Meeting;—B. Stewart, on the Theory of Exchanges, and its recent extension;—Drs. E. Schunck, R. Angus Smith, and H. E. Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District;—Dr. J. Hunt, on Ethno-Climatology; or, the Acclimatization of Man;—Prof. J. Thomson, on Experiments on the Gauging of Water by Triangular Notches;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—Prof. H. Hennessy, Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea;—Dr. P. L. Sclater and F. von Hochstetter, Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand;—J. G. Jeffreys, Report of the Results of Deep-sea Dredging in Zetland, with a Notice of several Species of Mollusca new to Science or to the British Isles;—Prof. J. Phillips, Contributions to a Report on the Physical Aspect of the Moon;—W. R. Birt, Contribution to a Report on the Physical Aspect of the Moon;—Dr. Collingwood and Mr. Byerley, Preliminary Report of the Dredging Committee of the Mersey and Dee;—Third Report of the Committee on Steamship Performance;—J. G. Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours;—R. Mallet, Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations;—T. Dobson, on the Explosions in British Coal-Mines during the year 1859;—J. Oldham, Continuation of Report on Steam Navigation at Hull;—Prof. G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland;—Prof. Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind;—Colonel Sykes, Report of the Balloon Committee;—Major-General Sabine, Report on the Repetition of the Magnetic Survey of England;—Interim Report of the Committee for

Dredging on the North and East Coasts of Scotland;—W. Fairbairn, on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities:—W. Fairbairn, Continuation of Report to determine the effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders;—Report of the Committee on the Law of Patents;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part III.

Together with the Transactions of the Sections, Mr. Fairbairn's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SECOND MEETING at Cambridge, October 1862, *Published at £1.*

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1861–62;—G. B. Airy, on the Strains in the Interior of Beams;—Archibald Smith and F. J. Evans, Report on the three Reports of the Liverpool Compass Committee;—Report on Tidal Observations on the Humber;—T. Aston, on Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences;—Extracts, relating to the Observatory at Kew, from a Report presented to the Portuguese Government, by Dr. J. A. de Souza;—H. T. Mennell, Report on the Dredging of the Northumberland Coast and Dogger Bank;—Dr. Cuthbert Collingwood, Report upon the best means of advancing Science through the agency of the Mercantile Marine;—Messrs. Williamson, Wheatstone, Thomson, Miller, Matthiessen, and Jenkin, Provisional Report on Standards of Electrical Resistance;—Preliminary Report of the Committee for investigating the Chemical and Mineralogical Composition of the Granites of Donegal;—Prof. H. Hennessy, on the Vertical Movements of the Atmosphere considered in connection with Storms and Changes of Weather;—Report of Committee on the application of Gauss's General Theory of Terrestrial Magnetism to the Magnetic Variations:—Fleeming Jenkin, on Thermo-electric Currents in Circuits of one Metal;—W. Fairbairn, on the Mechanical Properties of Iron Projectiles at High Velocities;—A. Cayley, Report on the Progress of the Solution of certain Special Problems of Dynamics;—Prof. G. G. Stokes, Report on Double Refraction;—Fourth Report of the Committee on Steamship Performance;—G. J. Symons, on the Fall of Rain in the British Isles in 1860 and 1861;—J. Ball, on Thermometric Observations in the Alps;—J. G. Jeffreys, Report of the Committee for Dredging on the North and East Coasts of Scotland;—Report of the Committee on Technical and Scientific Evidence in Courts of Law;—James Glaisher, Account of Eight Balloon Ascents in 1862;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part IV.

Together with the Transactions of the Sections, the Rev. Prof. R. Willis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-THIRD MEETING, at Newcastle-upon-Tyne, August and September 1863, *Published at £1 5s.*

CONTENTS:—Report of the Committee on the Application of Gun-cotton to Warlike Purposes;—A. Matthiessen, Report on the Chemical Nature of Alloys;—Report of the Committee on the Chemical and Mineralogical Constitution of the Granites of Donegal, and on the Rocks associated with them;—J. G. Jeffreys, Report of the Committee appointed for Exploring the Coasts of Shetland by means of the Dredge;—G. D. Gibb, Report on the Physiological Effects of the Bromide of Ammonium;—C. K. Aken, on the Transmutation of Spectral Rays, Part I.;—Dr. Robinson, Report of the Committee on Fog Signals;—Report of the Committee on Standards of Electrical Resistance;—E. Smith, Abstract of Report by the Indian Government on the Foods used by the Free and Jail Populations in India;—A. Gages, Synthetical Researches on the Formation of Minerals, &c.;—R. Mallet, Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours;—Report of the Committee on Observations of Luminous Meteors;—Fifth Report of the Committee on Steamship Performance;—G. J. Allman, Report on the Present State of our Knowledge of the Reproductive System in the Hydroida;—J. Glaisher, Account of Five Balloon Ascents made in 1863;—P. P. Carpenter, Supplementary Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America;—Prof. Airy, Report on Steam Boiler Explosions;—C. W. Siemens, Obser-

vations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 Atmospheres;—C. M. Palmer, on the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees;—Messrs. Richardson, Stevenson, and Clapham, on the Chemical Manufactures of the Northern Districts;—Messrs. Sopwith and Richardson, on the Local Manufacture of Lead, Copper, Zinc, Antimony, &c.:—Messrs. Daglish and Forster, on the Magnesian Limestone of Durham;—I. L. Bell, on the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field;—T. Spencer, on the Manufacture of Steel in the Northern District;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part V.

Together with the Transactions of the Sections, Sir William Armstrong's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, at Bath, September 1864, *Published at* 18*s*.

CONTENTS:—Report of the Committee for Observations of Luminous Meteors;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—T. S. Cobbold, Report of Experiments respecting the Development and Migration of the Entozoa;—B. W. Richardson, Report on the Physiological Action of Nitrite of Amyl;—J. Oldham, Report of the Committee on Tidal Observations;—G. S. Brady, Report on Deep-sea Dredging on the Coasts of Northumberland and Durham in 1864;-J. Glaisher, Account of Nine Balloon Ascents made in 1863 and 1864;—J. G. Jeffreys, Further Report on Shetland Dredgings;—Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report of the Committee on Standards of Electrical Resistance;—G. J. Symons, on the Fall of Rain in the British Isles in 1862 and 1863;—W. Fairbairn, Preliminary Investigation of the Mechanical Properties of the proposed Atlantic Cable.

Together with the Transactions of the Sections, Sir Charles Lyell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at* £1 5*s*.

CONTENTS:—J. G. Jeffreys, Report on Dredging among the Channel Isles;—F. Buckland, Report on the Cultivation of Oysters by Natural and Artificial Methods;—Report of the Committee for exploring Kent's Cavern;—Report of the Committee on Zoological Nomenclature:—Report on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Interim Report on the Resistance of Water to Floating and Immersed Bodies;—Report on Observations of Luminous Meteors;—Report on Dredging on the Coast of Aberdeenshire;—J. Glaisher, Account of Three Balloon Ascents:—Interim Report on the Transmission of Sound under Water;—G. J. Symons, on the Rainfall of the British Isles:—W. Fairbairn, on the Strength of Materials considered in relation to the Construction of Iron Ships;—Report of the Gun-Cotton Committee;—A. F. Osler, on the Horary and Diurnal Variations in the Direction and Motion of the Air at Wrottesley, Liverpool, and Birmingham:—B. W. Richardson, Second Report on the Physiological Action of certain of the Amyl Compounds;—Report on further Researches in the Lingula-flags of South Wales:—Report of the Lunar Committee for Mapping the Surface of the Moon;—Report on Standards of Electrical Resistance;—Report of the Committee appointed to communicate with the Russian Government respecting Magnetical Observations at Tiflis;—Appendix to Report on the Distribution of the Vertebrate Remains from the North Staffordshire Coal-field;—H. Woodward, First Report on the Structure and Classification of the Fossil Crustacea;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part VI.;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;—A. G. Findlay, on the Bed of the Ocean;—Prof. A. W. Williamson, on the Composition of Gases evolved by the Bath Spring called King's Bath.

Together with the Transactions of the Sections, Prof. Phillips's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SIXTH MEETING, at Nottingham, August 1866, *Published at £1 4s.*

CONTENTS:—Second Report on Kent's Cavern, Devonshire;—A. Matthiessen, Preliminary Report on the Chemical Nature of Cast Iron;—Report on Observations of Luminous Meteors;—W. S. Mitchell, Report on the Alum Bay Leaf-bed;—Report on the Resistance of Water to Floating and Immersed Bodies;—Dr. Norris, Report on Muscular Irritability;—Dr. Richardson, Report on the Physiological Action of certain compounds of Amyl and Ethyl;—H. Woodward, Second Report on the Structure and Classification of the Fossil Crustacea;—Second Report on the "Menevian Group," and the other Formations at St. David's, Pembrokeshire;—J. G. Jeffreys, Report on Dredging among the Hebrides;—Rev. A. M. Norman, Report on the Coasts of the Hebrides, Part II.;—J. Alder, Notices of some Invertebrata, in connexion with Mr. Jeffreys's Report;—G. S. Brady, Report on the *Ostracoda* dredged amongst the Hebrides;—Report on Dredging in the Moray Firth;—Report on the Transmission of Sound-Signals under Water;—Report of the Lunar Committee;—Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science;—J. Glaisher, Account of Three Balloon Ascents;—Report on the Extinct Birds of the Mascarene Islands;—Report on the Penetration of Iron-clad Ships by Steel Shot;—J. A. Wanklyn, Report on Isomerism among the Alcohols;—Report on Scientific Evidence in Courts of Law;—A. L. Adams, Second Report on Maltese Fossiliferous Caves, &c.

Together with the Transactions of the Sections, Mr. Grove's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SEVENTH MEETING, at Dundee, September 1867, *Published at £1 6s.*

CONTENTS:—Report of the Committee for Mapping the Surface of the Moon;—Third Report on Kent's Cavern, Devonshire;—On the present State of the Manufacture of Iron in Great Britain;—Third Report on the Structure and Classification of the Fossil Crustacea;—Report on the Physiological Action of the Methyl Compounds;—Preliminary Report on the Exploration of the Plant-Beds of North Greenland;—Report of the Steamship Performance Committee;—On the Meteorology of Port Louis, in the Island of Mauritius;—On the Construction and Works of the Highland Railway;—Experimental Researches on the Mechanical Properties of Steel:—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall:—Supplement to a Report on the Extinct Didine Birds of the Mascarene Islands;—Report on Observations of Luminous Meteors;—Fourth Report on Dredging among the Shetland Isles;—Preliminary Report on the Crustacea, &c., procured by the Shetland Dredging Committee in 1867:—Report on the Foraminifera obtained in the Shetland Seas;—Second Report of the Rainfall Committee:—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-EIGHTH MEETING, at Norwich, August 1868, *Published at £1 5s.*

CONTENTS:—Report of the Lunar Committee;—Fourth Report on Kent's Cavern, Devonshire;—On Puddling Iron;—Fourth Report on the Structure and Classification of the Fossil Crustacea;—Report on British Fossil Corals;—Report on Spectroscopic Investigations of Animal Substances;—Report of Steamship Performance Committee;—Spectrum Analysis of the Heavenly Bodies;—On Stellar Spectrometry;—Report on the Physiological Action of the Methyl and allied Compounds:—Report on the Action of Mercury on the Biliary Secretion;—Last Report on Dredging among the Shetland Isles;—Reports on the Crustacea, &c., and on the Annelida and Foraminifera from the Shetland Dredgings;—Report on the Chemical Nature of Cast Iron, Part I.;—Interim Report on the Safety of Merchant Ships and their Passengers;—Report on Observations of Luminous Meteors;—Preliminary Report on Mineral Veins containing Organic Remains;—Report on the Desirability of

Explorations between India and China;—Report of Rainfall Committee;—Report on Synthetical Researches on Organic Acids;—Report on Uniformity of Weights and Measures;—Report of the Committee on Tidal Observations;—Report of the Committee on Underground Temperature;—Changes of the Moon's Surface;—Report on Polyatomic Cyanides.

Together with the Transactions of the Sections, Dr. Hooker's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-NINTH MEETING, at Exeter, August 1869, *Published at £1 2s.*

CONTENTS:—Report on the Plant-beds of North Greenland;—Report on the existing knowledge on the Stability, Propulsion, and Sea going qualities of Ships; —Report on Steam-boiler Explosions;—Preliminary Report on the Determination of the Gases existing in Solution in Well-waters;—The Pressure of Taxation on Real Property;—On the Chemical Reactions of Light discovered by Prof. Tyndall;—On Fossils obtained at Kiltorkan Quarry, co. Kilkenny;—Report of the Lunar Committee:—Report on the Chemical Nature of Cast Iron;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Report on the Practicability of establishing "a Close Time" for the Protection of Indigenous Animals;—Experimental Researches on the Mechanical Properties of Steel;—Second Report on British Fossil Corals;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals for Photographing;—Report on the Rate of Increase of Underground Temperature;—Fifth Report on Kent's Cavern, Devonshire;—Report on the Connexion between Chemical Constitution and Physiological Action;—On Emission, Absorption, and Reflection of Obscure Heat;—Report on Observations of Luminous Meteors;—Report on Uniformity of Weights and Measures; —Report on the Treatment and Utilization of Sewage;—Supplement to Second Report of the Steamship-Performance Committee;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Mineral Veins in Carboniferous Limestone and their Organic Contents;—Notes on the Foraminifera of Mineral Veins and the Adjacent Strata;—Report of the Rainfall Committee;—Interim Report on the Laws of the Flow and Action of Water containing Solid Matter in Suspension;—Interim Report on Agricultural Machinery;—Report on the Physiological Action of Methyl and Allied Series;—On the Influence of Form considered in Relation to the Strength of Railway-axles and other portions of Machinery subjected to Rapid Alterations of Strain:—On the Penetration of Armour-plates with Long Shells of Large Capacity fired obliquely;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, Prof. Stokes's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTIETH MEETING, at Liverpool, September 1870, *Published at 18s.*

CONTENTS:—Report on Steam-boiler Explosions;—Report of the Committee on the Hæmatite Iron-ores of Great Britain and Ireland;—Report on the Sedimentary Deposits of the River Onny;—Report on the Chemical Nature of Cast Iron;—Report on the practicability of establishing a "Close Time" for the protection of Indigenous Animals;—Report on Standards of Electrical Resistance;—Sixth Report on Kent's Cavern;—Third Report on Underground Temperature;—Second Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on the Stability, Propulsion, and Sea-going Qualities of Ships;—Report on Earthquakes in Scotland;—Report on the Treatment and Utilization of Sewage;—Report on Observations of Luminous Meteors, 1869–70;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On a new Steam-power Meter;—Report on the Action of the Methyl and Allied Series;—Report of the Rainfall Committee;—Report on the Heat generated in the Blood in the Process of Arterialization;—Report on the best means of providing for Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. Huxley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIRST MEETING, at Edinburgh, August 1871, *Published at* 16*s.*

CONTENTS:—Seventh Report on Kent's Cavern;—Fourth Report on Underground Temperature;—Report on Observations of Luminous Meteors, 1870–71;—Fifth Report on the Structure and Classification of the Fossil Crustacea;—Report of the Committee appointed for the purpose of urging on Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effective comparison;—Report of the Committee appointed for the purpose of Superintending the Publication of Abstracts of Chemical Papers;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Second Provisional Report on the Thermal Conductivity of Metals;—Report on the Rainfall of the British Isles;—Third Report on the British Fossil Corals;—Report on the Heat generated in the Blood during the Process of Arterialization;—Report of the Committee appointed to consider the subject of Physiological Experimentation;—Report on the Physiological Action of Organic Chemical Compounds;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on Steam-Boiler Explosions;—Report on the Treatment and Utilization of Sewage;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Preliminary Report on the Thermal Equivalents of the Oxides of Chlorine;-Report on the practicability of establishing a "Close Time" for the protection of Indigenous Animals;—Report on Earthquakes in Scotland;—Report on the best means of providing for a Uniformity of Weights and Measures;—Report on Tidal Observations.

Together with the Transactions of the Sections, Sir William Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SECOND MEETING, at Brighton, August 1872, *Published at* £1 4*s.*

CONTENTS:—Report on the Gaussian Constants for the Year 1829;—Second Supplementary Report on the Extinct Birds of the Mascarene Islands;—Report of the Committee for Superintending the Monthly Reports of the Progress of Chemistry;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—Eighth Report on Kent's Cavern;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Fourth Report on the Fauna of South Devon;—Preliminary Report of the Committee appointed to Construct and Print Catalogues of Spectral Rays arranged upon a Scale of Wave-numbers;—Third Report on Steam-Boiler Explosions;—Report on Observations of Luminous Meteors, 1871–72;—Experiments on the Surface-friction experienced by a Plane moving through Water;—Report of the Committee on the Antagonism between the Action of Active Substances;—Fifth Report on Underground Temperature;—Preliminary Report of the Committee on Siemens's Electrical-Resistance Pyrometer:—Fourth Report on the Treatment and Utilization of Sewage;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships and Currents:—Report on the Rainfall of the British Isles;—Report of the Committee on a Geographical Exploration of the Country of Moab;—Sur l'élimination des Fonctions Arbitraires;—Report on the Discovery of Fossils in certain remote parts of the North-western Highlands;—Report of the Committee on Earthquakes in Scotland;—Fourth Report on Carboniferous-Limestone Corals;—Report of the Committee to consider the mode in which new Inventions and Claims for Reward in respect of adopted Inventions are examined and dealt with by the different Departments of Government;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Report on the Mollusca of Europe;—Report of the Committee for investigating the Chemical Constitution and Optical Properties of Essential Oils:—Report on the practicability of establishing a "Close Time" for the preservation of Indigenous Animals;—Sixth Report on the Structure and Classification of Fossil Crustacea;—Report of the Committee appointed to organize an Expedition for observing the Solar Eclipse of Dec. 12, 1871;—Preliminary Report of a Committee on Terato-embryological Inquiries;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On the Brighton Waterworks;—On Amsler's Planimeter.

Together with the Transactions of the Sections, Dr. Carpenter's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-THIRD MEETING, at Bradford, September 1873, *Published at £1 5s.*

CONTENTS:—Report of the Committee on Mathematical Tables;—Observations on the Application of Machinery to the Cutting of Coal in Mines;—Concluding Report on the Maltese Fossil Elephants;—Report of the Committee for ascertaining the Existence in different parts of the United Kingdom of any Erratic Blocks or Boulders;—Fourth Report on Earthquakes in Scotland;—Ninth Report on Kent's Cavern;—On the Flint and Chert Implements found in Kent's Cavern;—Report of the Committee for Investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report of Inquiry into the Method of making Gold-assays; —Fifth Report on the Selection and Nomenclature of Dynamical and Electrical Units;—Report of the Committee on the Labyrinthodonts of the Coal-measures;—Report of the Committee appointed to construct and print Catalogues of Spectral Rays;—Report of the Committee appointed to explore the Settle Caves;—Sixth Report on Underground Temperature;—Report on the Rainfall of the British Isles;—Seventh Report on Researches in Fossil Crustacea;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on the desirability of establishing a "Close Time" for the preservation of Indigenous Animals;—Report on Luminous Meteors; -On the Visibility of the Dark Side of Venus;—Report of the Committee for the Foundation of Zoological Stations in different parts of the World;—Second Report of the Committee for collecting Fossils from North-western Scotland;—Fifth Report on the Treatment and Utilization of Sewage;—Report of the Committee on Monthly Reports of the Progress of Chemistry;—On the Bradford Waterworks;—Report on the possibility of Improving the Methods of Instruction in Elementary Geometry; —Interim Report of the Committee on Instruments for Measuring the Speed of Ships, &c.;—Report of the Committee for Determinating High Temperatures by means of the Refrangibility of Light evolved by Fluid or Solid Substances;—On a periodicity of Cyclones and Rainfall in connexion with Sun-spot Periodicity;—Fifth Report on the Structure of Carboniferous-Limestone Corals;—Report of the Committee on preparing and publishing brief forms of Instructions for Travellers, Ethnologists, &c.;—Preliminary Note from the Committee on the Influence of Forests on the Rainfall;—Report of the Sub-Wealden Exploration Committee;—Report of the Committee on Machinery for obtaining a Record of the Roughness of the Sea and Measurement of Waves near shore;—Report on Science Lectures and Organization;—Second Report on Science Lectures and Organization.

Together with the Transactions of the Sections, Prof. A. W. Williamson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FOURTH MEETING, at Belfast, August 1874, *Published at £1 5s.*

CONTENTS:—Tenth Report on Kent's Cavern;—Report for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Second Report of the Sub-Wealden Exploration Committee;—On the Recent Progress and Present State of Systematic Botany;—Report of the Committee for investigating the Nature of Intestinal Secretion;—Report of the Committee on the Teaching of Physics in Schools;—Preliminary Report for investigating Isomeric Cresols and their Derivatives;—Third Report of the Committee for collecting Fossils from localities in North-western Scotland;—Report on the Rainfall of the British Isles;—On the Belfast Harbour;—Report of Inquiry into the Method of making Gold-assays;—Report of a Committee on Experiments to determine the Thermal Conductivities of certain Rocks;—Second Report on the Exploration of the Settle Caves;—On the Industrial uses of the Upper Bann River;—Report of the Committee on the Structure and Classification of the Labyrinthodont;—Second Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c;—Sixth Report on the Treatment and Utilization of Sewage;—Report on the Anthropological Notes and Queries for the use of Travellers;—On Cyclone and Rainfall Periodicities;—Fifth Report on Earthquakes in Scotland;—Report of the Committee appointed to prepare and print Tables of Wave-numbers;—Report of the Committee for testing the new Pyrometer of Mr. Siemens;—Report to the Lords Commissioners of the Admiralty on Experiments for the Determination of the Frictional Resistance of Water on a Surface,

&c.;—Second Report for the Selection and Nomenclature of Dynamical and Electrical Units;—On Instruments for measuring the Speed of Ships;—Report of the Committee on the possibility of establishing a "Close Time" for the Protection of Indigenous Animals;—Report of the Committee to inquire into the economic effects of Combinations of Labourers and Capitalists;—Preliminary Report on Dredging on the Coasts of Durham and North Yorkshire;—Report on Luminous Meteors;—Report on the best means of providing for a Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. John Tyndall's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIFTH MEETING, at Bristol, August 1875, *Published at £1 5s.*

CONTENTS:—Eleventh Report on Kent's Cavern;—Seventh Report on Underground Temperature;—Report on the Zoological Station at Naples;—Report of a Committee appointed to inquire into the Methods employed in the Estimation of Potash and Phosphoric Acid in Commercial Products;—Report on the present state of our Knowledge of the Crustacea;—Second Report on the Thermal Conductivities of certain Rocks;—Preliminary Report of the Committee for extending the Observations on the Specific Volumes of Liquids;—Sixth Report on Earthquakes in Scotland;—Seventh Report on the Treatment and Utilization of Sewage;—Report of the Committee for furthering the Palestine Explorations;—Third Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.;—Report of the Rainfall Committee;—Report of the Committee for investigating Isomeric Cresols and their Derivatives;—Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—On the Steering of Screw-Steamers;—Second Report of the Committee on Combinations of Capital and Labour;—Report on the Method of making Gold-assays;—Eighth Report on Underground Temperature;—Tides in the River Mersey;—Sixth Report of the Committee on the Structure of Carboniferous Corals;—Report of the Committee appointed to explore the Settle Caves;—On the River Avon (Bristol), its Drainage-Area, &c.;—Report of the Committee on the possibility of establishing a "Close Time" for the Protection of Indigenous Animals;—Report of the Committee appointed to superintend the Publication of the Monthly Reports of the Progress of Chemistry;—Report on Dredging off the Coasts of Durham and North Yorkshire in 1874;—Report on Luminous Meteors;—On the Analytical Forms called Trees;—Report of the Committee on Mathematical Tables;—Report of the Committee on Mathematical Notation and Printing;—Second Report of the Committee for investigating Intestinal Secretion;—Third Report of the Sub-Wealden Exploration Committee.

Together with the Transactions of the Sections, Sir John Hawkshaw's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SIXTH MEETING, at Glasgow, September 1876, *Published at £1 5s.*

CONTENTS:—Twelfth Report on Kent's Cavern;—Report on Improving the Methods of Instruction in Elementary Geometry;—Results of a Comparison of the British-Association Units of Electrical Resistance;—Third Report on the Thermal Conductivities of certain Rocks;—Report of the Committee on the practicability of adopting a Common Measure of Value in the Assessment of Direct Taxation;—Report of the Committee for testing experimentally Ohm's Law;—Report of the Committee on the possibility of establishing a "Close Time" for the Protection of Indigenous Animals;—Report of the Committee on the Effect of Propellers on the Steering of Vessels;—On the Investigation of the Steering Qualities of Ships;—Seventh Report on Earthquakes in Scotland;—Report on the present state of our Knowledge of the Crustacea;—Second Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fourth Report of the Committee on the Erratic Blocks of England and Wales, &c.;—Fourth Report of the Committee on the Exploration of the Settle Caves (Victoria Cave);—Report on Observations of Luminous Meteors,

1875–76;—Report on the Rainfall of the British Isles, 1875–76;—Ninth Report on Underground Temperature;—Nitrous Oxide in the Gaseous and Liquid States;—Eighth Report on the Treatment and Utilization of Sewage;—Improved Investigations on the Flow of Water through Orifices, with Objections to the modes of treatment commonly adopted;—Report of the Anthropometric Committee;—On Cyclone and Rainfall Periodicities in connexion with the Sun-spot Periodicity;—Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee on Tidal Observations:—Third Report of the Committee on the Conditions of Intestinal Secretion and Movement;—Report of the Committee for collecting and suggesting subjects for Chemical Research.

Together with the Transactions of the Sections, Dr. T. Andrews's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SEVENTH MEETING, at Plymouth, August 1877, *Published at £1 4s.*

CONTENTS:—Thirteenth Report on Kent's Cavern;—Second and Third Reports on the Methods employed in the estimation of Potash and Phosphoric Acid in Commercial Products:—Report on the present state of our Knowledge of the Crustacea (Part III.);—Third Report on the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fifth Report on the Erratic Blocks of England, Wales, and Ireland;—Fourth Report on the Thermal Conductivities of certain Rocks:—Report on Observations of Luminous Meteors, 1876–77;—Tenth Report on Underground Temperature;—Report on the Effect of Propellers on the Steering of Vessels;—Report on the possibility of establishing a "Close Time" for the Protection of Indigenous Animals;—Report on some Double Compounds of Nickel and Cobalt;—Fifth Report on the Exploration of the Settle Caves (Victoria Cave):—Report on the Datum Level of the Ordnance Survey of Great Britain;—Report on the Zoological Station at Naples;—Report of the Anthropometric Committee;—Report on the Conditions under which Liquid Carbonic Acid exists in Rocks and Minerals.

Together with the Transactions of the Sections, Prof. Allen Thomson's Address, and Recommendations of the Association and its Committees.

BRITISH ASSOCIATION

FOR

THE ADVANCEMENT OF SCIENCE

LIST

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CORRECTED TO DECEMBER 1878

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LIST OF MEMBERS

OF THE

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1878.

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§ indicates Annual Subscribers entitled to the Annual Report.
§§ indicates Annual Subscribers who will be entitled to the Report if their Subscriptions are paid by December 31, 1878.
‡ indicates Subscribers not entitled to the Annual Report.
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Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of Residence should be sent to the Assistant Secretary, 22 Albemarle Street, London, W.

Year of Election.

Abbatt, Richard, F.R.A.S. Marlborough House, Burgess Hill, Sussex.
1866. ‡Abbott, George J., United States Consul, Sheffield and Nottingham.
1863. *ABEL, FREDERICK AUGUSTUS, C.B., F.R.S., F.C.S., Director of the Chemical Establishment of the War Department, Royal Arsenal, Woolwich.
1856. ‡Abercrombie, John, M.D. 13 Suffolk-square, Cheltenham.
1863. *Abernethy, James. 4 Delahay-street, Westminster, London, S.W.
1873. ‡Abernethy, James. Ferry-hill, Aberdeen.
1860. ‡Abernethy, Robert. Ferry-hill, Aberdeen.
1873. *ABNEY, Captain W. de W., R.E., F.R.S., F.R.A.S., F.C.S. 3 St. Alban's-road, Kensington, London, W.
1854. ‡Abraham, John. 87 Bold-street, Liverpool.
1877. §§Ace, Rev. Daniel, D.D. Laughton, near Gainsborough, Lincolnshire.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.
1877. *Acland, Francis E. Dyke, R.A. Oxford.
1873. *Acland, Rev. H. D. Loughton, Essex.
ACLAND, HENRY W. D., M.A., M.D., LL.D., F.R.S., F.R.G.S., Radcliffe Librarian and Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.
1877. *Acland, Theodore Dyke, M.A. 13 Vincent-square, Westminster, S.W.
1860. ‡ACLAND, Sir THOMAS DYKE, Bart., M.A., D.C.L., M.P. Sprydoncote, Exeter; and Athenæum Club, London, S.W.

Year of Election.

Adair, John. 13 Merrion-square North, Dublin.

1872. ‡ADAMS, A. LEITH, M.A., M.B., F.R.S., F.G.S.. Professor of Zoology, Royal College of Science for Ireland. 18 Clarendon-gardens, Maida Hill, W.; and Junior United Service Club, Charles-street, St. James's, London, S.W.

1876. ‡Adams, James. 9 Royal-crescent West, Glasgow.

*ADAMS, JOHN COUCH, M.A., LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndsean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.

1871.§§Adams, John R. 3 College-gardens, Dulwich, Surrey, S.E.

1877.§§ADAMS, WILLIAM. 3 Sussex-terrace, Plymouth.

1869. *ADAMS, WILLIAM GRYLLS, M.A., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 43 Notting Hill-square, London, W.

1873. ‡Adams-Acton, John. Margutta House, 103 Marylebone-road, London, N.W.

ADDERLEY, The Right Hon. Sir CHARLES BOWYER, M.P. Hams-hall, Coleshill, Warwickshire.

Adelaide, The Right Rev. Augustus Short, D.D., Bishop of. South Australia.

1860. **Adie, Patrick. Grove Cottage, Barnes, London, S.W.*

1865. *Adkins, Henry. Ley Hill, Oakfield, near Birmingham.

1864. *Ainsworth, David. The Flosh, Cleator, Carnforth.

1871. *Ainsworth, John Stirling. The Flosh, Cleator, Carnforth.

Ainsworth, Peter. Smithills Hall, Bolton.

1842. *Ainsworth, Thomas. The Flosh, Cleator, Carnforth.

1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.

1859. ‡AIRLIE, The Right Hon. the Earl of, K.T. Holly Lodge, Campden Hill, London, W.; and Airlie Castle, Forfarshire.

AIRY, Sir GEORGE BIDDELL, K.C.B., M.A., LL.D., D.C.L., F.R.S., F.R.A.S., Astronomer Royal. The Royal Observatory, Greenwich, S E.

1871. §Aitken, John. Darroch, Falkirk, N.B.

Akroyd, Edward. Bankfield, Halifax.

1862. ‡ALCOCK, Sir RUTHERFORD, K.C.B., D.C.L., F.R.G.S. The Athenæum Club, Pall Mall, London, S.W.

1861. ‡Alcock, Thomas, M.D. Side Brook, Salemoor, Manchester.

1872. *Alcock, Thomas, M.D. Oakfield, Ashton-on-Mersey, Manchester.

*Aldam, William. Frickley Hall, near Doncaster.

ALDERSON, Sir JAMES, M.A., M.D., D.C.L., F.R.S., Consulting Physician to St. Mary's Hospital. 17 Berkeley-square, London, W.

1859. ‡ALEXANDER, General Sir JAMES EDWARD, K.C.B., K.C.L.S., F.R.S.E., F.R.A.S., F.R.G.S. Westerton, Bridge of Allan, N.B.

1873. ‡Alexander, Reginald, M.D. 13 Hallfield-road, Bradford, Yorkshire.

1858. ‡ALEXANDER, WILLIAM, M.D. Halifax.

1850. ‡Alexander, Rev. William Lindsay, D.D., F.R.S.E. Pinkieburn, Musselburgh, by Edinburgh.

1867. ‡Alison, George L. C. Dundee.

1859. ‡Allan, Alexander. Scottish Central Railway, Perth.

1871. ‡Allan, G., C.E. 17 Leadenhall-street, London, E.C.

1871. §ALLEN, ALFRED, H., F.C.S. 1 Surrey-street, Sheffield.

1878. §Allen, John Romilly. 5 Albert-terrace, Regent's Park, London, N.W.

1861. ‡Allen, Richard. Didsbury, near Manchester.

Allen, William. 50 Henry-street, Dublin.

1852. *ALLEN, WILLIAM J. C., Secretary to the Royal Belfast Academical Institution. Ulster Bank, Belfast.

Year of Election.

1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.

*Allman, George J., M.D., F.R.S. L. & E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. (President Elect.) Queen Anne's Mansions, St. James's Park, London, S.W.; and Parkstone, Dorset.

1875. *Alston, Edward R., F.L.S., F.Z.S. 22a Dorset-street, Portman-square, London, W.

1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.

1876. ‡Anderson, Alexander. 1 St. James's-place, Hillhead, Glasgow.

1878. §Anderson, Beresford. Saint Ville, Killiney.

1850. ‡Anderson, Charles William. Cleadon, South Shields.

1850. ‡Anderson, John. 31 St. Bernard's-crescent, Edinburgh.

1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.

1876. ‡Anderson, Matthew. 137 St. Vincent-street, Glasgow.

1859. ‡Anderson, Patrick. 15 King-street, Dundee.

1875. ‡Anderson, Captain S., R.E. Junior United Service Club, Charles-street, St. James's, London, S.W.

1870. ‡*Anderson, Thomas Darnley. West Dingle, Liverpool.*

*Andrews, Thomas, M.D., LL.D., F.R.S., Hon. F.R.S.E., M.R.I.A., F.C.S., Vice-President and Professor of Chemistry, Queen's College, Belfast. Queen's College, Belfast.

1857. ‡Andrews, William. The Hill, Monkstown, Co. Dublin.

1877. §Angell, John. 81 Ducie-grove, Oxford-street, Manchester.

1859. ‡Angus, John. Town House, Aberdeen.

1878. §Anson, Frederick H. 9 Delahay-street, Westminster, S.W.

*Ansted, David Thomas, M.A., F.R.S., F.G.S., F.R.G.S. 1 Prince's-street, Storey's-gate, Westminster, S.W.; and Melton, Suffolk.

Anthony, John, M.D. 6 Greenfield-crescent, Edgbaston, Birmingham.

Apjohn, James, M.D., F.R.S., F.C.S., M.R.I.A., Professor of Mineralogy at Dublin University. South Hill, Blackrock, Co. Dublin.

1868. ‡Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.

1870. ‡Archer, Francis, jun. 3 Brunswick-street, Liverpool.

1855. *Archer, Professor Thomas C., F.R.S.E., Director of the Museum of Science and Art, Edinburgh. West Newington House, Edinburgh.

1874. ‡Archer, William, F.R.S., M.R.I.A. St. Brendan's, Grosvenor-road East, Rathmines, Dublin.

1851. ‡Argyll, His Grace the Duke of, K.T., D.C.L., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inverary, Argyleshire.

1865. ‡*Armitage, J. W., M.D. 9 Huntriss-row, Scarborough.*

1861. ‡Armitage, William. 7 Meal-street, Mosley-street, Manchester.

1867. *Armitstead, George. Errol Park, Errol, N.B.

1873. §Armstrong, Henry E., Ph.D., F.R.S., F.C.S. London Institution, Finsbury-circus, London, E.C.

1878. ‡Armstrong, James. 28a Renfield-street, Glasgow.

1874. ‡Armstrong, James T., F.C.S. Plym Villa, Clifton-road, Tuebrook, Liverpool.

Armstrong, Thomas. Higher Broughton, Manchester.

1857. *Armstrong, Sir William George, C.B., LL.D., D.C.L., F.R.S. 8 Great George-street, London, S.W.; and Jesmond Dene, Newcastle-upon-Tyne.

1871. ‡Arnot, William, F.C.S. St. Margaret's, Kirkintilloch, N.B.

1870. ‡Arnott, Thomas Reid. Bramshill, Harlesden Green, London, N.W.

1853. *Arthur, Rev. William, M.A. Clapham Common, London, S.W.

Year of Election.

1870. *Ash, Dr. T. Linnington. Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. District Asylum, Londonderry.
1873. §Ashton, John. Gorse Bank House, Windsor-road, Oldham.
1842. *Ashton, Thomas, M.D. 8 Royal Wells-terrace, Cheltenham.
Ashton, Thomas. Ford Bank, Didsbury, Manchester.
1866. ‡Ashwell, Henry. Mount-street, New Basford, Nottingham.
*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
Ashworth, Henry. Turton, near Bolton.
1861. ‡Aspland, Alfred. Dukinfield, Ashton-under-Lyne.
1875. *Aspland, W. Gaskell. Kilrea, Co. Derry, Ireland.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Thomas. 4 Elm-court, Temple, London, E.C.
1872. §Atchison, Arthur T., M.A. 60 Warwick-road, Earl's Court, London, S.W.
1873. ‡*Atchison, D. G. Tyersall Hall, Yorkshire.*
1858. ‡Atherton, Charles. Sandover, Isle of Wight.
1866. ‡Atherton, J. H., F.C.S. Long-row, Nottingham.
1865. ‡Atkin, Alfred. Griffin's Hill, Birmingham.
1861. ‡Atkin, Eli. Newton Heath, Manchester.
1865. *ATKINSON, EDMUND, Ph.D., F.C.S. Portesbery Hill, Camberley, Surrey.
1863. *Atkinson, G. Clayton. 21 Windsor-terrace, Newcastle-on-Tyne.
1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. *Atkinson, John Hastings. 12 East Parade, Leeds.
1842. *Atkinson, Joseph Beavington. Stratford House, 113 Abingdon-road, Kensington, London, W.
1858. Atkinson, William. Claremont, Southport.
1863. *ATTFIELD, Professor J., Ph.D., F.C.S. 17 Bloomsbury-square, London, W.C.
1860. *Austin-Gourlay, Rev. William E. C., M.A. The Rectory, Stanton St. John, near Oxford.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1867. ‡Avison, Thomas, F.S.A. Fulwood Park, Liverpool.
1878. *Aylmer, Sir Gerald George, Bart. Donadea Castle, Kilcock, Co. Kildare.
1877. *Ayrton, Professor W. E. The Imperial College of Engineering, Tokio, Japan. (Care of Mrs. J. C. Chaplin, 98 Palace-gardens-terrace, Kensington, London, W.)
1853. *Ayrton, W. S., F.S.A. Cliffden, Saltburn-by-the-Sea.

*BABINGTON, CHARLES CARDALE, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
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Backhouse, Thomas James. Sunderland.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1877. §§Badock, W. F. Badminton House, Clifton Park, Bristol.
1870. §§Bailey, Dr. F. J. 51 Grove-street, Liverpool.
1878. §Bailey, John. 3 Blackhall-place, Dublin.
1865. ‡Bailey, Samuel, F.G.S. The Peck, Walsall.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1866. ‡Baillon, Andrew. St. Mary's Gate, Nottingham.
1866. ‡Baillon, L. St. Mary's Gate, Nottingham.
1878. §Baily, Walter. 176 Haverstock-hill, London, N.W.
1857. ‡BAILY, WILLIAM HELLIER, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 14 Hume-street; and Apsley Lodge, 92 Rathgar-road, Dublin.

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1873. §Bain, James. 3 Park-terrace, Glasgow.
1865. ‡BAIN, Rev. W. J. Glenlark Villa, Leamington.
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*BAINES, EDWARD. Belgrave Mansions, Grosvenor-gardens, London, S.W.; and St. Ann's Hill, Burley, Leeds.
1858. ‡Baines, Frederick. Burley, near Leeds.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1866. ‡Baker, Francis B. Sherwood-street, Nottingham.
1865. ‡Baker, James P. Wolverhampton.
1861. *Baker, John. Gatley Hill, Cheadle, Manchester.
1865. ‡Baker, Robert L. Barham House, Leamington.
1849. *Baker, William. 63 Gloucester-place, Hyde Park, London, W.
1863. §§Baker, William. 6 Taptonville, Sheffield.
1875. *Baker, W. Mills. Moorland House, Stoke Bishop, near Bristol.
1875. ‡BAKER, W. PROCTOR. Brislington, Bristol.
1871. *BALFOUR, FRANCIS MAITLAND, M.A., F.R.S. Trinity College, Cambridge.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
1875. §Balfour, Isaac Bayley, D.Sc. 27 Inverleith-row, Edinburgh.
*BALFOUR, JOHN HUTTON, M.D., M.A., F.R.S. L. & E., F.L.S., Professor of Botany in the University of Edinburgh. 27 Inverleith-row, Edinburgh.
1878. *Ball, Charles Bent, M.D. Blaenavon, Monmouthshire.
*BALL, JOHN, M.A., F.R.S., F.L.S., M.R.I.A. 10 Southwell-gardens, South Kensington, London, S.W.
1866. *BALL, ROBERT STAWELL, M.A., LL D., F.R.S., F.R.A.S., Andrews Professor of Astronomy in the University of Dublin, and Royal Astronomer. The Observatory, Dunsink, Co. Dublin.
1863. ‡Ball, Thomas. Bramcote, Nottingham.
1878. §BALL, VALENTINE, F.G.S. Calcutta.
*Ball, William. Bruce-grove, Tottenham, London; and Glen Rothay, near Ambleside, Westmoreland.
1876. ‡Ballantyne, James. Southcroft, Rutherglen, Glasgow.
1870. ‡Balmain, William H., F.C.S. Spring Cottage, Great St. Helen's, Lancashire.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1874. *Bangay, Frederick Arthur. Cheadle, Cheshire.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1870. ‡BANISTER, Rev. WILLIAM, B.A. St. James's Mount, Liverpool.
1861. ‡*Bannermann, James Alexander. Limefield House, Higher Broughton, near Manchester.*
1866. ‡Barber, John. Long-row, Nottingham.
1861. *Barbour, George. Bankhead, Broxton, Chester.
1859. ‡Barbour, George F. 11 George-square, Edinburgh.
*Barbour, Robert. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
Barclay, Charles, F.S.A. Bury Hill, Dorking.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
Barclay, James. Catrine, Ayrshire.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1876. *Barclay, Robert. 21 Park-terrace, Glasgow.
1868. *Barclay, W. L. 54 Lombard-street, London, E.C.
1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.

Year of Election.

1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.
1857. ‡Barker, John, M.D., Curator of the Royal College of Surgeons of Ireland. 83 Waterloo-road, Dublin.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. ‡BARKLY, Sir HENRY, K.C.B., F.R.S., F.R.G.S. 25 Queen's-gate-terrace, London, S.W.
1873. ‡Barlow, Crawford, B.A. 2 Old Palace-yard, Westminster, S.W.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
Barlow, Peter. 10 Lower Mount-street, Dublin.
1857. ‡BARLOW, PETER WILLIAM, F.R.S., F.G.S. 26 Great George-street, Westminster, S.W.
1873. §BARLOW, W. H., C.E., F.R.S. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1868. §Barnes, Richard H. (Care of Messrs. Collyer, 4 Bedford-row, London, W.C.)
Barnes, Thomas Addison. 40 *Chester-street, Wrexham.*
*Barnett, Richard, M.R.C.S. 3 Heath-terrace, Worcester.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1861. *Barr, William R., F.G.S. Fernside, Cheadle Hulme, Cheshire.
1860. ‡Barrett, T. B. High-street, Welshpool, Montgomery.
1872. *BARRETT, W. F., F.R.S.E., M.R.I.A., F C.S., Professor of Physics in the Royal College of Science, Dublin.
1874. ‡Barrington, R. M. Fassaroe, Bray, Co. Wicklow.
1874. §Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. St. Winified's, Lincoln.
1866. †Barron, William. Elvaston Nurseries, Borrowash, Derby.
1858. ‡BARRY, Rev. Canon, D.D., D.C.L., Principal of King's College, London, W.C.
1862. *Barry, Charles. 15 Pembridge-square, Bayswater, London, W.
1875. ‡Barry, John Wolfe. 23 Delahay-street, Westminster, S.W.
Barstow, Thomas. Garrow Hill, near York.
1858. *Bartholomew, Charles. Castle Hill House, Ealing, Middlesex, W.
1855. ‡Bartholomew, Hugh. New Gasworks, Glasgow.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1873. §Bartley, George C. T. National Penny Bank, 270 Oxford-street, London, W.
1868. *Barton, Edward (27th Inniskillens). Clonelly, Ireland.
1857. ‡Barton, Folloit W. Clonelly, Co. Fermanagh.
1852. ‡Barton, James. Farndreg, Dundalk.
1864. ‡Bartrum, John S. 41 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1876. §§Bassano, Alexander. 12 Montagu-place, London, W.
1876. §§Bassano, Clement. Jesus College, Cambridge.
1866. *BASSETT, HENRY. 44 St. Paul's-road, Camden-square, London, N.W.
1866. ‡Bassett, Richard. Pelham-street, Nottingham.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡BASTIAN, H. CHARLTON, M.D., M.A., F.R.S., F.L.S., Professor of Pathological Anatomy at University College. 20 Queen Anne-street, London, W.
1848. ‡BATE, C. SPENCE, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.

Year of Election.

1873. *Bateman, Daniel. Low Moor, near Bradford, Yorkshire.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
Bateman, James, M.A., F.R.S., F.R.G.S., F.L.S. 9 Hyde Park-gate South, London, W.
1842. *Bateman, John Frederic, C.E., F.R.S., F.G.S., F.R.G.S. 16 Great George-street, London, S.W.
1864. ‡Bates, Henry Walter, Assist.-Sec. R.G.S., F.L.S. 1 Savile-row, London, W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1851. ‡Bath and Wells, The Right Rev. Lord Arthur Hervey, Lord Bishop of. The Palace, Wells, Somerset.
1869. ‡Batten, John Winterbotham. 35 Palace-gardens-terrace, Kensington, London, S.W.
1863. §Bauerman, H., F.G.S. 22 Acre-lane, Brixton, London, S.W.
1861. ‡Baxendell, Joseph, F.R.A.S. 108 Stock-street, Manchester.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, John B. Craig Tay House, Dundee.
1867. ‡Baxter, The Right Hon. William Edward, M.P. Ashcliffe, Dundee.
1868. ‡Bayes, William, M.D. 58 Brook-street, London, W.
1851. *Bayley, George. 16 London-street, Fenchurch-street, London, E.C.
1866. ‡Bayley, Thomas. Lenton, Nottingham.
1854. ‡*Baylis, C. O., M.D. 22 Devonshire-road, Claughton, Birkenhead.*
Bayly, John. Seven Trees, Plymouth.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
Bazley, Thomas Sebastian, M.A. Hatherop Castle, Fairford, Gloucestershire.
1860. *Beale, Lionel S., M.D., F.R.S., Professor of Pathological Anatomy in King's College. 61 Grosvenor-street, London, W.
1872. ‡Beanes, Edward, F.C.S. The White House, North Dulwich, Surrey, S.E.
1870. ‡Beard, Rev. Charles. 13 South-hill-road, Toxteth Park, Liverpool.
*Beatson, William. Chemical Works, Rotherham.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.M.S., F.S.S. Athenæum Club, Pall Mall, London, S.W.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1871. *Beazley, Captain George G., F.R.G.S. Army and Navy Club, Pall Mall, London, S.W.
1859. *Beck, Joseph, F.R.A.S. 31 Cornhill, London, E.C.
1864. §Becker, Miss Lydia E. Whalley Range, Manchester.
1860. ‡Beckles, Samuel H., F.R.S., F.G.S. 9 Grand-parade, St. Leonard's-on-Sea.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §Beddoe, John, M.D., F.R.S. Clifton, Bristol.
1878. §Bedson, P. Phillips, D.Sc. Oak Leigh, Marple, near Stockport.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1865. *Belavenetz, I., Captain of the Russian Imperial Navy, F.R.I.G.S., M.S.C.M.A., Superintendent of the Compass Observatory, Cronstadt. (Care of Messrs. Baring Brothers, Bishopsgate-street, London, E.C.)
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1873. §Bell, A. P. Royal Exchange, Manchester.
1871. §Bell, Charles B. Spring-bank, Hull.

Year of Election.

Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. ‡Bell, George. Windsor-buildings, Dumbarton.
1860. ‡Bell, Rev. George Charles, M.A. Marborough College, Wilts.
1855. ‡Bell, Capt. Henry. Chalfont Lodge, Cheltenham.
1862. *BELL, ISAAC LOWTHIAN, M.P., F.R.S., F.C.S., M.I.C.E. Rounton Grange, by Northallerton.
1875. §Bell, James, F.C.S. The Laboratory, Somerset House, London, W.C.
1871. *Bell, J. Carter, F.C.S. Kersal Clough, Higher Broughton, Manchester.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. §Bell, R. Bruce. 2 Clifton-place, Glasgow.
BELL, THOMAS, F.R.S., F.L.S., F.G.S. The Wakes, Selborne, near Alton, Hants.
1863. *Bell, Thomas. Crosby Court, Northallerton.
1867. ‡Bell, Thomas. Belmont, Dundee.
1875. ‡Bell, William. 36 Park-road, New Wandsworth, Surrey, S.W.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1854. ‡*Bellhouse, William Dawson. 1 Park-street, Leeds.*
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1866. *BELPER, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.G.S. 75 Eaton-square, London, S.W.; and Kingston Hall, Derby.
1864. *Bendyshe, T. 7 Belgrave-villas, Margate.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1871. ‡*Bennett, F. J. 12 Hillmarten-road, Camden-road, London, N.*
1870. *Bennett, William. 109 Shaw-street, Liverpool.
1870. *Bennett, William, jun. Oak Hill Park, Old Swan, near Liverpool.
1852. *Bennoch, Francis, F.S.A. 19 Tavistock-square, London, W.C.
1857. ‡Benson, Charles. 11 Fitzwilliam-square West, Dublin.
Benson, Robert, jun. Fairfield, Manchester.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870. ‡Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.
1848. ‡BENTHAM, GEORGE, F.R.S., F.R.G.S., F.L.S. 25 Wilton-place, Knightsbridge, London, S.W.
1842. Bentley, John. 2 Portland-place, London, W.
1863. §BENTLEY, ROBERT, F.L.S., Professor of Botany in King's College. 1 Trebovir-road, South Kensington, London, S.W.
1875. ‡Beor, Henry R. Scientific Club, Savile-row, London, W.
1876. ‡Bergius, Walter C. 9 Loudon-terrace, Hillhead, Glasgow.
1868. ‡BERKELEY, Rev. M. J., M.A., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1848. ‡Berrington, Arthur V. D. Woodlands Castle, near Swansea.
1866. ‡Berry, Rev. Arthur George. Monyash Parsonage, Bakewell, Derbyshire.
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A., F.R.S. St. John's College, Cambridge.
1865. *BESSEMER, HENRY. Denmark Hill, Camberwell, London, S.E.
1858. ‡Best, William. Leydon-terrace, Leeds.
Bethune, Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1876. *Bettany, G. T., B.A., B.Sc. Caius College, Cambridge.
1859. ‡Beveridge, Robert, M.B. 36 King-street, Aberdeen.
1874. *Bevington, James B. Merle Wood, Sevenoaks.
1863. ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland.

Year of Election.

*Bickerdike, Rev. John, M.A. St. Mary's Vicarage, Leeds.
1870. ‡Bickerton, A.W., F.C.S. Hartley Institution, Southampton.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1864. ‡Biggs, Robert. 16 Green Park, Bath.
1855. ‡*Billings, Robert William. 4 St. Mary's-road, Canonbury, London, N.*
Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.
1877. §§Binder, W. J., B.A. Barnsley.
1842. BINNEY, EDWARD WILLIAM, F.C.S., F.G.S. Cheetham Hill, Manchester.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
Birchall, Edwin, F.L.S. Douglas, Isle of Man.
Birchall, Henry. College House, Bradford.
1866. *Birkin, Richard. Aspley Hall, near Nottingham.
*Birks, Rev. Thomas Rawson, M.A., Professor of Moral Philosophy in the University of Cambridge. 7 Brookside, Cambridge.
1841. *BIRT, WILLIAM RADCLIFF, F.R.A.S. Hawkenbury, Palmerston-road, Buckhurst Hill.
1871. *BISCHOF, GUSTAV. 4 Hart-street, Bloomsbury, London, W.C.
1868. ‡Bishop, John. Thorpe Hamlet, Norwich.
1866. ‡Bishop, Thomas. Bramcote, Nottingham.
1877. §§BLACHFORD, The Right Hon. Lord, K.C.M.G. Cornwood, Ivybridge.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1834. Blackburn, Bewicke. 14 Victoria-road, Kensington, London, W.
1876. ‡Blackburn, Hugh, M.A., Professor of Mathematics in the University of Glasgow.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1877. §§Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1859. ‡Blackie, John Stewart, M.A., Professor of Greek in the University of Edinburgh.
1876. ‡Blackie, Robert. 7 Great Western-terrace. Glasgow.
1855. *BLACKIE, W. G., Ph.D., F.R.G.S. 17 Stanhope-street, Glasgow.
1870. ‡Blackmore, W. Founder's-court, Lothbury, London, E.C.
*BLACKWALL, Rev. JOHN, F.L.S. Hendre House, near Llanrwst, Denbighshire.
1878. §Blair, Matthew. Oakshaw, Paisley.
1863. ‡Blake, C. Carter, D.Sc. Westminster Hospital School of Medicine, Broad Sanctuary, Westminster, S.W.
1849. *BLAKE, HENRY WOLLASTON, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, London, W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1878. §Blakeney. Rev. Canon, M.A. The Vicarage, Sheffield.
1845. ‡*Blakesley, Rev. J. W., B.D. Ware Vicarage, Hertfordshire.*
1861. §Blakiston, Matthew, F.R.G.S. 18 Wilton-crescent, London, S.W.
Blakiston, Peyton, M.D., F.R.S. 140 Harley-street, London, W.
1868. ‡*Blanc, Henry, M.D. 9 Bedford-street, Bedford-square, London, W.C.*
1869. ‡Blanford, W. T., F.R.S., F.G.S., F.R.G.S., Geological Survey of India. Calcutta.
*BLOMEFIELD, Rev. LEONARD, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
1878. §*Blood, T. Lloyd.*
Blore, Edward, LL.D., F.R.S., F.R.G.S., F.S.A. 4 Manchester-square, London, W.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.

Year of Election.

1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Capt. Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1858. *Blythe, William. Holland Bank, Church, near Accrington.
1870. ‡Boardman, Edward. Queen-street, Norwich.
1866. §Bogg, Thomas Wemyss. 2 East Ascent, St. Leonard's.
1876 §Bogue, David. 192 Piccadilly, London, W.
1859. *BOHN, HENRY G., F.L.S., F.R.A.S., F.R.G.S., F.S.S. North End House, Twickenham.
1871. ‡Bohn, Mrs. North End House, Twickenham.
1859. ‡Bolster, Rev. Prebendary John A. Cork.
1876. ‡Bolton, J. C. Carbrook, Stirling.
Bolton, R. L. Laurel Mount, Aigburth-road, Liverpool.
1866. ‡Bond, Banks. Low Pavement, Nottingham.
Bond, Henry John Hayes, M.D. Cambridge.
1871. §Bonney, Rev. Thomas George, M.A., F.R.S., F.S.A., F.G.S. St. John's College, Cambridge.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. §Booth, James. Elmfield, Rochdale.
1861. *Booth, William. Hollybank, Cornbrook, Manchester.
1876. §§Booth, William H. Trinity College, Oxford.
1861. *Borchardt, Louis, M.D. Barton Arcade, Manchester.
1849. ‡Boreham, William W., F.R.A.S. The Mount, Haverhill, Newmarket.
1876. *Borland, William. 260 West George-street, Glasgow.
1863. ‡Borries, Theodore. Lovaine-crescent, Newcastle-on-Tyne.
1876. *Bosanquet, R. H. M., M.A., F.C.S., F.R.S.A. St. John's College, Oxford.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1867. §Botly, William. F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1858. ‡Botterill, John. Burley, near Leeds.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1871. *BOTTOMLEY, JAMES THOMSON, M.A., F.R.S.E., F.C.S. The University, Glasgow.
Bottomley, William. 14 Brunswick-gardens, Kensington, London, W.
1876. §Bottomley, William, jun. 14 Brunswick-gardens, Kensington, London, W.
1850. ‡Bouch, Thomas, C.E. Oxford-terrace, Edinburgh.
1870. ‡Boult, Swinton. 1 Dale-street, Liverpool.
1868. ‡Boulton, W. S. Norwich.
1866. §Bourne, Stephen, F.S.S. Abberley, Wallington, Surrey.
1872. ‡Bovill, William Edward. 29 James-street, Buckingham-gate, London, S.W.
1870. ‡Bower, Anthony. Bowersdale, Seaforth, Liverpool.
1867. ‡Bower, Dr. John. Perth.
1856. *Bowlby, Miss F. E. 20 Lansdowne-parade, Cheltenham.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
Bowman, William, F.R.S., F.R.C.S. 5 Clifford-street, London, W.
1869. ‡Bowring, Charles T. Elmsleigh, Prince's-park, Liverpool.
1863. ‡*Bowron, James. South Stockton-on-Tees.*
1863. §Boyd, Edward Fenwick. Moor House, near Durham.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡BOYLE, Rev. G. D. Soho House, Handsworth, Birmingham.

Year of Election.

1872. *Brabrook, E. W., F.S.A., Dir. A.I. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Mount Henley, Sydenham Hill, London, S.E.
1870.§§Brace, Edmund. 3 Spring-gardens, Kelvinside, Glasgow.
Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, Warwickshire.
1861. *Bradshaw, William. Slade House, Green-walk, Bowdon, Cheshire.
1842. *Brady, Sir Antonio, J.P., F.G.S. Maryland Point, Stratford, Essex, E.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
Brady, Daniel F., M.D. 5 Gardiner's-row, Dublin.
1863. ‡Brady, George S. 22 Fawcett-street, Sunderland.
1862. §Brady, Henry Bowman, F.R.S., F.L.S., F.G.S. Hillfield, Gateshead.
1875. ‡Bragge, William, F.S.A., F.G.S. Shirle Hill, Sheffield.
1864. §Braham, Philip, F.C.S. 6 George-street, Bath.
1870. §Braidwood, Dr. Delemere-terrace, Birkenhead.
1864. §Braikenridge, Rev. George Weare, M.A., F.L.S. Clevedon, Somerset.
1865. §Bramwell, Frederick J., M.I.C.E., F.R.S. 37 Great George-street, London, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. Dickleburgh Rectory, Scole, Norfolk.
1852. ‡Brazier, James S., F.C.S., Professor of Chemistry in Marischal College and University of Aberdeen.
1857. ‡Brazill, Thomas. 12 Holles-street, Dublin.
1869. *Breadalbane, The Right Hon. the Earl of. Taymouth Castle, N.B.; and Carlton Club, Pall Mall, London, S.W.
1873. ‡Breffit, Edgar. Castleford, near Normanton.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1877.§§Brent, Francis. 19 Clarendon-place, Plymouth.
1860. ‡Brett, G. Salford.
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1875. §Briant, T. Hampton Wick, Kingston-on-Thames.
1867. ‡Bridgman, William Kenceley. 69 St. Giles's-street, Norwich.
1870. *Bridson, Joseph R. Belle Isle, Windermere.
1870. ‡Brierley, Joseph, C.E. New Market-street, Blackburn.
1870. *Brigg, John. Broomfield, Keighley, Yorkshire.
1866. *Briggs, Arthur. Cragg Royd, Rawdon, near Leeds.
1866.§§Briggs, Joseph. Barrow-in-Furness.
1863. *Bright, Sir Charles Tilston, C.E., F.G.S., F.R.G.S., F.R.A.S. 20 Bolton-gardens, London, S.W.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
Bright, The Right Hon. John, M.P. Rochdale, Lancashire.
1868. ‡Brine, Commander Lindesay. Army and Navy Club, Pall Mall, London, S.W.
1878. §Britten, James, F.L.S. Department of Botany, British Museum, London, W.C.
1842. *Broadbent, Thomas. Marsden-square, Manchester.*
1859. *Brodhurst, Bernard Edward. 20 Grosvenor-street, Grosvenor-square, London, W.
1847. ‡Brodie, Sir Benjamin C., Bart., M.A., D.C.L., F.R.S., F.C.S. Brockham Warren, Reigate.
1834. ‡Brodie, Rev. James, F.G.S. Monimail, Fifeshire.
1865. ‡Brodie, Rev. Peter Bellenger, M.A., F.G.S. Rowington Vicarage, near Warwick.

Year of
Election.

1853. ‡Bromby, J.H., M.A. The Charter House, Hull.
1878. §Brook, George. Huddersfield, Yorkshire.
*BROOKE, CHARLES, M.A., F.R.S., F.R.C.S. 16 Fitzroy-square, London, W.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. Ingham. Thornhill Rectory, Dewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1878. §Brooke, Sir Victor, Bart., F.L.S. Colebrook, Brookeborough, Co. Fermanagh.
1863. §Brooks, John Crosse. Wallsend, Newcastle-on-Tyne.
1846. *Brooks, Thomas. Cranshaw Hall, Rawtenstall, Manchester.
Brooks, William. Ordfall Hill, East Retford, Nottinghamshire.
1874. §§Broom, William. 20 Woodlands-terrace, Glasgow.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
*BROUN, JOHN ALLAN, F.R.S. 9 Abercorn-place, St. John's Wood, London, N.W.
1863. *BROWN, ALEXANDER CRUM, M.D., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1867. ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. §Brown, David. 93 Abbey-hill, Edinburgh.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1870. §BROWN, HORACE T. The Bank, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1870. *BROWN, J. CAMPBELL, D.Sc., F.C.S. Royal Infirmary School of Medicine, Liverpool.
1876. §Brown, John. Edenderry House, Belfast.
1859. ‡Brown, Rev. John Crombie, LL.D., F.L.S. Berwick-on-Tweed.
1874. ‡Brown, John S. Edenderry, Shaw's Bridge, Belfast.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1871. ‡BROWN, ROBERT, M.A., Ph.D., F.L.S., F.R.G.S. 26 Guildford-road, Albert-square, London, S.W.
1868. ‡Brown, Samuel. Grafton House, Swindon, Wilts.
*Brown, Thomas. Evesham Lawn, Pittville, Cheltenham.
*Brown, William. 11 Maiden-terrace, Dartmouth Park, London, N.
1855. ‡Brown, William. 33 Berkeley-terrace, Glasgow.
1850. ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
1865. ‡Brown, William. 41A New-street, Birmingham.
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Northside, St. John's, Sevenoaks, Kent.
1875. ‡Browne, Walter R. Bridgwater.
1865. *Browne, William, M.D. The Friary, Lichfield.
1865. ‡Browning, John, F.R.A.S. 111 Minories, London. E.
1855. §§Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1853. ‡*Brownlow, William B. Villa-place, Hull.*
1863. *Brunel, H. M. 23 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 23 Delahay-street, Westminster, S.W.
1875. *Brunlees, James, C.E., F.G.S. 5 Victoria-street, Westminster, S.W.
1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1868. ‡BRUNTON, T. LAUDER, M.D., F.R.S. 50 Welbeck-street, London, W.
1878. §Brutton, Joseph. Yeovil.

Year of Election.

1877.§§Bryant, George. 82 Claverton-street, Pimlico, London, S.W.
1875. ‡Bryant, G. Squier. 15 White Ladies'-road, Clifton, Bristol.
1875.§§Bryant, Miss S. A. The Castle, Denbigh.
1861. ‡Bryce, James. York-place, Higher Broughton, Manchester.
Bryce, Rev. R. J., LL.D., Principal of Belfast Academy. Belfast.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1867. ‡Buccleuch and Queensberry, His Grace the Duke of, K.G., D.C.L., F.R.S. L. & E., F.L.S. Whitehall-gardens, London, S.W.; and Dalkeith House, Edinburgh.
1871. §Buchan, Alexander, M.A., F.R.S.E., Sec. Scottish Meteorological Society. 72 Northumberland-street, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
Buchanan, Andrew, M.D., Professor of the Institutes of Medicine in the University of Glasgow. 4 Ethol-place, Glasgow.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. Poulton-cum-Seacombe, Cheshire.
1871. ‡Buchanan, John Y. 10 Moray-place, Edinburgh.
1864. §Buckle, Rev. George, M.A. The Rectory, Weston-super-Mare.
1865. *Buckley, Henry. 27 Wheeley's-road, Edgbaston, Birmingham.
1848. *Buckman, Professor James, F.L.S., F.G.S. Bradford Abbas, Sherborne, Dorsetshire.
1869. ‡Bucknill, J. C., M.D., F.R S. 39 Wimpole-street, London, W.
1851. *Buckton, George Bowdler, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1848. *Budd, James Palmer. Ystalyfera Iron Works, Swansea.
1875. §Budgett, Samuel. Cotham House, Bristol.
1871. §Bulloch, Matthew. 11 Park-circus, Glasgow.
1845. *Bunbury, Sir Charles James Fox, Bart., F.R.S., F.L.S., F.G.S., F.R.G.S. Barton Hall, Bury St. Edmunds.
1865. ‡Bunce, John Mackray. 'Journal' Office, New-street, Birmingham.
1863. §Bunning, T. Wood. Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.
1842. *Burd, John. 5 Gower-street, London, W.C.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. Stratton-street, Piccadilly, London, W.
1874. ‡Burdon, Henry, M.D. Clandeboye, Belfast.
1872. *Burgess, Herbert. 62 High-street, Battle, Sussex.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1859. ‡Burnett, Newell. Belmont-street, Aberdeen.
1877.§§Burns, David, C.E. Alston, Carlisle.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1877.§§Burt, J. Kendall. Kendal.
1874. ‡Burt, Rev. J. T. Broadmoor, Berks.
1866. *Burton, Frederick M., F.G.S. Highfield, Gainsborough.
1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1855. *Busk, George, F.R.S., V.P.L.S., F.G.S. 52 Harley-street, Cavendish-square, London, W.
1878. §Butcher, J. G., M.A. 22 Collingham-place, London, S.W.
1857. ‡Butt, Isaac, Q.C., M.P. 64 Eccles-street, Dublin.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1870. ‡Buxton, David, Principal of the Liverpool Deaf and Dumb Institution, Oxford-street, Liverpool.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1872. ‡Buxton, Sir T. Fowell, Bart. Warlies, Waltham Abbey, Essex.

Year of Election.

1854. ‡BYERLEY, ISAAC, F.L.S. Seacombe, Liverpool.
Byng, William Bateman. 2 Bank-street, Ipswich.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1875. §Byrom, W. Ascroft, F.G.S. 27 King-street, Wigan.

1858. §Cail, John. Stokesley, Yorkshire.
1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1858. *Caine, Rev. William, M.A. Christ Church Rectory, Denton, near Manchester.
1876. §§Caird, Alexander M'Neel. Genoch, Wigtownshire.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1876. §§Caird, Edward B. 8 Scotland-street, Glasgow.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1855. *Caird, James Tennant. Belleaire, Greenock.
1875. ‡Caldicott, Rev. J. W., D.D. The Grammar School, Bristol.
1877. §§Caldwell, Miss. 2 Victoria-terrace, Portobello, Edinburgh.
1868. ‡Caley, A. J. Norwich.
1868. ‡Caley, W. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1853. ‡Calver, Captain E. K., R.N., F.R.S. The Grange, Redhill, Surrey.
1876. ‡Cameron, Charles, M.D., LL.D., M.P. 1 Huntly-gardens, Glasgow.
1857. ‡CAMERON, CHARLES A., M.D. 15 Pembroke-road, Dublin.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1857. *Campbell, Dugald, F.C.S. 7 Quality-court, Chancery-lane, London, W.C.
1874. *CAMPBELL, Sir GEORGE, K.C.S.I., M.P., D.C.L., F.R.G.S. 13 Cornwall-gardens, South Kensington, London, S.W.; and Edenwood, Cupar, Fife.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
*Campbell, Sir James. 129 Bath-street, Glasgow.
1876. ‡Campbell. James A. 3 Claremont-terrace, Glasgow.
Campbell. John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1872. ‡CAMPBELL, Rev. J. R., D.D. 5 Eldon-place, Manningham-lane, Bradford, Yorkshire.
1859. ‡Campbell, William. Dunmore, Argyllshire.
1871. ‡Campbell, William Hunter, LL.D. Georgetown, Demerara, British Guiana. (Messrs. Ridgway & Sons, 2 Waterloo-place, London, S.W.)
CAMPBELL-JOHNSTON, ALEXANDER ROBERT, F.R.S. 84 St. George's-square, London, S.W.
1876. §Campion, Frank, F.G.S., F.R.G.S. The Mount, Duffield-road, Derby.
1862. *CAMPION, Rev. Dr. WILLIAM M. Queen's College, Cambridge.
1868. *Cann, William. 9 Southernhay, Exeter.
1873. *Carbutt, Edward Hamer, C.E. St. Ann's, Burley, Leeds, Yorkshire.
*Carew, William Henry Pole. Antony, Torpoint, Devonport.
1877. §§Carkeet, John, C.E. 3 St. Andrew's-place, Plymouth.
1876. §§Carlile, Thomas. 5 St. James's-terrace, Glasgow.
CARLISLE, The Right Rev. HARVEY GOODWIN, D.D., Lord Bishop of Carlisle.
1861. ‡Carlton, James. Mosley-street, Manchester.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. ‡Carmichael, George. 11 Dudhope-terrace, Dundee.
Carmichael, John T. C. Messrs. Todd & Co., Cork.
1876. ‡Carmichael, Neil, M.D. 22 South Cumberland-street, Glasgow.

Year of
Election.
1871. ‡CARPENTER, CHARLES. Brunswick-square, Brighton.
1871. *Carpenter, P. Herbert. Eton College, Windsor.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1845. ‡CARPENTER, WILLIAM B., C.B., M.D., LL.D., F.R.S., F.L.S., F.G.S., Registrar of the University of London. 56 Regent's Park-road, London, N.W.
1872. §CARPENTER, WILLIAM LANT, B.A., B.Sc., F.C.S. Winifred House, Pembroke-road, Clifton, Bristol.
1842. *Carr, William, M.D., F.L.S., F.R.C.S. Lee Grove, Blackheath, S.E.
1867. §CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, W.C.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1857. ‡CARTE, ALEXANDER, M.D. Royal Dublin Society, Dublin.
1868. ‡Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, C.E., F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 62 Elizabeth-street, Liverpool.
*CARTMELL, Rev. JAMES, D.D., F.G.S., Master of Christ's College. Christ College Lodge, Cambridge.
1878. §Cartwright, H. S. Magherafelt Manor, Co. Derry.
1870. §Cartwright, Joshua, A.I.C.E., Borough Surveyor. Bury, Lancashire.
1862. ‡Carulla, Facundo, F.A.S.L. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1868. ‡Cary, Joseph Henry. Newmarket-road, Norwich.
1866. ‡Casella, L. P., F.R.A.S. 147 Holborn Bars, London, E.C.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William. 38 Elmfield-terrace, Saville Park, Halifax.
Castle, Charles. Clifton, Bristol.
1874. ‡Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. 18A Abercromby-square, Liverpool.
1853. ‡Cator, John B., Commander R.N. 1 Adelaide-street, Hull.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1873. *Cavendish, Lord Frederick, M.P. 21 Carlton House-terrace, London, S.W.
1849. ‡Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. §CAYLEY, ARTHUR, LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Mathemathics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1870. ‡Chadburn, C. H. Lord-street, Liverpool.
1858. *Chadwick, Charles, M.D. Lynncourt, Broadwater Down, Tunbridge Wells.
1860. ‡CHADWICK, DAVID, M.P. The Poplars, Herne Hill, London, S.E.
1842. CHADWICK, EDWIN, C.B. Richmond, Surrey.
1842. Chadwick, Elias, M.A. Pudleston Court, near Leominster.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1861. ‡Chadwick, Thomas. Wilmslow Grange, Cheshire.
*CHALLIS, Rev. JAMES, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy in the University of Cambridge. 2 Trumpington-street, Cambridge.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1865. ‡CHAMBERLAIN, J. H. Christ Church-buildings, Birmingham.
1868. ‡*Chamberlain, Robert. Catton, Norwich.*
1842. Chambers, George. High Green, Sheffield.

Year of Election.

1868. ‡Chambers, W. O. Lowestoft, Suffolk.
1877. *Champernowne, Arthur, M.A., F.G.S. Dartington Hall, Totnes, Devon.
*Champney, Henry Nelson. 4 New-street, York.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. Four Oaks Park, Sutton Coldfield, Birmingham.
1865. §Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Frewen Hall, Oxford.
1877. §Chapman, T. Algernon. Burghill, Hereford.
1866. ‡Chapman, William. The Park, Nottingham.
1871. §Chappell, William, F.S.A. Strafford Lodge, Oatlands Park, Weybridge Station.
1874. ‡Charles, John James, M.A., M.D. 11 Fisherwick-place, Belfast
1871. ‡Charles, T. C., M.D. Queen's College, Belfast.
1836. CHARLESWORTH, EDWARD, F.G.S. 113A Strand, London, W.C.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1863. ‡Charlton, Edward, M.D. 7 Eldon-square, Newcastle-on-Tyne.
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. Junior Garrick Club, Adelphi-terrace, London, W.C.
Chatto, W. J. P. Union Club, Trafalgar-square, London, S.W.
1867. *Chatwood, Samuel. 5 Wentworth-place, Bolton.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, S.W.
1874. *Chermside, Lieutenant H. C., R.E. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.
1872. §CHICHESTER, The Right Hon. the Earl of. Stanmer House, Lewes.
CHICHESTER, The Right Rev. RICHARD DURNFORD, D.D., Lord Bishop of. Chichester.
1865. *Child, Gilbert W., M.A., M.D., F.L.S. Lee Place, Charlbury, Oxon.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1859. ‡Christie, John, M.D. 46 School-hill, Aberdeen.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
CHRISTISON, Sir ROBERT, Bart., M.D., D.C.L., F.R.S.E., Professor of Dietetics, Materia Medica, and Pharmacy in the University of Edinburgh. Edinburgh.
1875. *Christopher, George, F.C.S. 8 Rectory-grove, Clapham, London, S.W.
1876. *CHRYSTAL, G., B.A., Professor of Mathematics. The University, St. Andrew's, N.B.
1870. §CHURCH, A. H., F.C.S., Professor of Chemistry in the Royal Agricultural College, Cirencester.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1857. ‡Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.
1868. ‡Clabburn, W. H. Thorpe, Norwich.
1863. ‡*Clapham, A. 3 Oxford-street, Newcastle-on-Tyne.*
1863. ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
1855. §CLAPHAM, ROBERT CALVERT. Earsdon House, Earsdon, Newcastle-on-Tyne.
1869. §Clapp, Frederick. 44 Magdalen-street, Exeter.
1857. ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.
1859. ‡Clark, David. Coupar Angus, Fifeshire.
1876. ‡*Clark, David P. Glasgow.*
1877. *Clark, F. J. 20 Bootham, York.
Clark, G. T. Bombay; and Athenæum Club, London, S.W.

Year of
Election.

1876. ‡Clark, George W. Glasgow.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1861. ‡Clark, Latimer. 5 Westminster-chambers, Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
Clarke, George. Mosley-street, Manchester.
1872. *Clarke, Hyde. 32 St. George's-square, Pimlico, London, S.W.
1875. ‡Clarke, John Henry. 4 Worcester-terrace, Clifton, Bristol.
1861. *Clarke, John Hope. Lark Hill House, Edgeley, Stockport.
1877.§§Clarke, Professor John W. University of Chicago, Illinois.
1851. ‡Clarke, Joshua, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1856. *Clay, Colonel William. The Slopes, Wallasea, Cheshire.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1850. ‡Cleghorn, Hugh, M.D., F.L.S., late Conservator of Forests, Madras. Stravithie, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1861. §Cleland, John, M.D., F.R.S., Professor of Anatomy in the University of Glasgow. 2 College, Glasgow.
1857. ‡Clements, Henry. Dromin, Listowel, Ireland.
‡Clerk, Rev. D. M. Deverill, Warminster, Wiltshire.
1852. ‡Clibborn, Edward. Royal Irish Academy, Dublin.
1873. §Cliff, John, F.G.S. Halton, Runcorn.
1869. ‡Clifford, William Kingdon, M.A., F.R.S., Professor of Applied Mathematics and Mechanics in University College, London. 26 Colville-road, Bayswater, London, W.
1861. *Clifton, R. Bellamy, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1854. ‡Close, The Very Rev. Francis, M.A. Carlisle.
1866. §Close, Thomas, F.S.A. St. James's-street, Nottingham.
1878. §Close, Rev. Maxwell, F.G.S. 40 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1859. ‡Clouston, Rev. Charles. Sandwick, Orkney.
1861. *Clouston, Peter. 1 Park Terrace, Glasgow.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
1855. *Coats, Thomas. Fergeslie House, Paisley.
Cobb, Edward. 13 Great Bedford-street, Bath.
1851. *Cobbold, John Chevallier. Holywells, Ipswich; and Athenæum Club, London, S.W.
1864. ‡Cobbold, T. Spencer, M.D., F.R.S., F.L.S., Professor of Botany and Helminthology in the Royal Veterinary College, London. 74 Portsdown-road, Maida Hill, London, W.
1864. *Cochrane, James Henry. Monmouth House, Wellington-terrace, Clevedon, Somersetshire.
1861. *Coe, Rev. Charles C., F.R.G S. Highfield, Manchester-road, Bolton.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1876. ‡Colbourn, E. Rushton. 5 Marchmont-terrace, Hillhead, Glasgow.

Year of
Election.
1853. ‡Colchester, William, F.G.S. Springfield House, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1876. §Colebrooke, Sir T. E., Bart., M.P., F.R.G.S. 14 South-street, Park-lane, London, W.; and Abington House, Abington, N.B.
1860. ‡Coleman, J. J., F.C.S. 69 St. George's-place, Glasgow.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1878. §Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, London, W.
1857. ‡Colles, William, M.D. 21 Stephen's-green, Dublin.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1854. ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 4 Grove-terrace, Belvedere-road, Upper Norwood, Surrey, S.E.
1861. *Collingwood, J. Frederick, F.G.S. Anthropological Institute, 4 St. Martin's-place, London, W.C.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. §COLLINS, J. H., F.G.S. 57 Lemon-street, Truro, Cornwall.
1876.§§Collins, William. 3 Park-terrace East, Glasgow.
Collis, Stephen Edward. Listowel, Ireland.
1868. *COLMAN, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1870. ‡Coltart, Robert. The Hollies, Aigburth-road, Liverpool.
Colthurst, John. Clifton, Bristol.
1874. ‡Combe, James. Ormiston House, Belfast.
*COMPTON, The Ven. Lord ALWYN. Castle Ashby, Northamptonshire; and 145 Piccadilly, London, W.
1846. *Compton, Lord William. 145 Piccadilly, London, W.
1852. ‡Connal, Michael. 16 Lynedock-terrace, Glasgow.
1871. *Connor, Charles C. Hope House, College Park East, Belfast.
1876. ‡Cook, James. 162 North-street, Glasgow.
1876. *COOKE, CONRAD W., C.E. 5 Nelson-terrace, Clapham Common, London, S.W.
1863. ‡COOKE, EDWARD WILLIAM, R.A., F.R.S., F.R.G.S., F.L.S., F.G.S. Glen Andred, Groombridge, Sussex; and Athenæum Club, Pall Mall, London, S.W.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
Cooke, James R., M.A. 73 Blessington-street, Dublin.
Cooke, J. B. Cavendish-road, Birkenhead.
1868. ‡COOKE, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
1878. §Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
Cooke, Rev. T. L., M.A. Magdalen College, Oxford.
Cooke, Sir William Fothergill. 31 Castle-street, Farnham, Surrey.
1859. *Cooke, William Henry, M.A., Q.C., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1863. ‡Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.
1869. §Cooling, Edwin, F.R.G.S. Mile Ash, Derby.
1850. ‡COOPER, Sir HENRY, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1875. ‡Cooper, T. T., F.R.G.S. Care of Messrs. King & Co., Cornhill, London, E.C.
1868. ‡Cooper, W. J. The Old Palace, Richmond, Surrey.
1846. ‡Cooper, William White, F.R.C.S. 19 Berkeley-square, London, W.
1878. §Cope, Rev. S. W. Bramley, Leeds.
1871. ‡*Copeland, Ralph, Ph.D. Parsonstown, Ireland.*
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1863. ‡Coppin, John. North Shields.

Year of Election.

1842. Corbett, Edward. Ravenoak, Cheadle-hulme, Cheshire.
1855. ‡Corbett, Joseph Henry, M D., Professor of Anatomy and Physiology in Queen's College, Cork.
1870. *CORFIELD, W. H., M.A., M.B., F.G.S., Professor of Hygiène and Public Health in University College. 10 Bolton-row, Mayfair, London, W.
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. Brazennose-street, Manchester.
1855. ‡Cotterill, Rev. Henry, Bishop of Edinburgh. Edinburgh.
1874. *Cotterill, J. H., M.A., F.R.S., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. ‡COTTON, General FREDERICK C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, London, S.W.
1869. ‡COTTON, WILLIAM. Pennsylvania, Exeter.
*Cotton, Rev. William Charles, M.A. Vicarage, Frodsham, Cheshire.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1874. §§Courtauld, John M. Bocking Bridge, Braintree, Essex.
1865. ‡Courtauld, Samuel, F.R.A.S. 76 Lancaster-gate, London, W.; and Gosfield Hall, Essex.
1834. ‡Cowan, Charles. 38 West Register-street, Edinburgh.
1876. ‡Cowan, J. B. 159 Bath-street, Glasgow.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William. Hawthorn House, Horsham.
1873. *Cowans, John. Cranford, Middlesex.
Cowie, The Very Rev. Benjamin Morgan, M.A., B.D., Dean of Manchester. The Deanery, Manchester.
1871. ‡Cowper, C. E. 3 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.I.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. 18 Windsor-street, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1867. ‡Cox, James. Clement Park, Lochee, Dundee.
1870. *Cox, James. 8 Falkner-square, Liverpool.
Cox, Robert. 25 Rutland-street, Edinburgh.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1866. *Cox, William H. 50 Newhall-street, Birmingham.
1871. ‡*Cox, William J. 2 Vanburgh-place, Leith.*
Craig, J. T. Gibson, F.R.S.E. 24 York-place, Edinburgh.
1859. ‡*Craig, S. The Wallands, Lewes, Sussex.*
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1857. ‡Crampton, Rev. Josiah. The Rectory, Florence Court, Co. Fermanagh, Ireland.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1876. ‡Crawford, Chalmond, M.P. Ridemon, Crosscar.
1871. *Crawford, William Caldwell, M.A. Eagle Foundry, Port Dundas, Glasgow.
1871. ‡Crawshaw, Edward. Burnley, Lancashire.
1870. *Crawshay, Mrs. Robert. Cyfarthfa Castle, Merthyr Tydvil.
1876. *Crewdson, Rev. George. St. George's Vicarage, Kendal.
Creyke, The Venerable Archdeacon. Bolton Percy Rectory, Tadcaster.
1858. ‡Crofts, John. Hillary-place, Leeds.

Year of Election.

1878. §Croke, John O'Byrne. 1 Casino-terrace, Clontarf, Dublin.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1866. ‡Cronin, William. 4 Brunel-terrace, Nottingham.
1870. ‡Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.
1865. §CROOKES, WILLIAM, F.R.S., F.C.S. 20 Mornington-road, Regent's Park, London, N.W.
1855. ‡Cropper, Rev. John. Wareham, Dorsetshire.
1870. ‡Crosfield, C. J. 16 Alexandra-drive, Prince's Park, Liverpool.
1870. ‡Crosfield, William, sen. Annesley, Aigburth, Liverpool.
1870. *Crosfield, William, jun. 16 Alexandra-drive, Prince's Park, Liverpool.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1867. §CROSSKEY, Rev. H. W., F.G.S. 28 George-road, Edgbaston, Birmingham.
1853. ‡Crosskill, William, C.E. Beverley, Yorkshire.
1870. *Crossley, Edward, F.R A.S. Bemerside, Halifax.
1871. ‡Crossley, Herbert. Broomfield, Halifax.
1866. *Crossley, Louis J., F.M.S. Moorside Observatory, near Halifax.
1861. §Crowley, Henry. Trafalgar-road, Birkdale Park, Southport.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1860. ‡Cruickshank, John. City of Glasgow Bank, Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1873. §§Crust, Walter. Hall-street, Spalding.
Culley, Robert. Bank of Ireland, Dublin.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1876. ‡Cunlif, Richard S. Carlton House, Stirling.
1861. *Cunliffe, Edward Thomas. The Elms, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. The Elms, Handforth, Manchester.
1877. §Cunningham, D. J., M.D. University of Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S. Professor of Natural History in Queen's College, Belfast.
1855. ‡Cunningham, William A. 2 Broadwalk, Buxton.
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1866. ‡Cunnington, John. 68 Oakley-square, Bedford New Town, London, N.W.
1867. *Cursetjee, Manockjee, F.R.G.S., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡CURTIS, Professor ARTHUR HILL, LL.D. Queen's College, Galway.
1878. §Curtis, William. Caramore, Sutton.
1834. *Cuthbert, John Richmond. 40 Chapel-street, Liverpool.

1863. ‡Daglish, John. Hetton, Durham.
1854. ‡Daglish, Robert, C.E. Orrell Cottage, near Wigan.
1863. ‡Dale, J. B. South Shields.
1853. ‡Dale, Rev. P. Steele, M.A. Hollingfare, Warrington.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1870. ‡Dallinger, Rev. W. H. Great Crosby, Liverpool.
Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
1859. ‡Dalrymple, Charles Elphinstone. West Hall, Aberdeenshire.
1859. ‡Dalrymple, Colonel. Troup, Scotland.
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.

Year of Election.

*Dalton, Rev. J. E., B.D. Seagrave, Loughborough.
Dalziel, John, M.D. Holm of Drumlanrig, Thornhill, Dumfriesshire.
1862. ‡Danby, T. W. Downing College, Cambridge.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1873. ‡*Danehill, F. H. Vale Hall, Horwich, Bolton, Lancashire.*
1876.§§Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1861. *Darbishire, Robert Dukinfield, B.A., F.G.S. 26 George-street, Manchester.
1876. ‡Darling, G. Erskine. 247 West George-street, Glasgow.
Darwin, Charles R., M.A., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E. and M.R.I.A. Down, near Bromley, Kent.
1878. §Darwin, Horace. Down, near Bromley, Kent.
1848. ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S.W.
1872. §Davenport, John T. 64 Marine Parade, Brighton.
Davey, Richard, F.G.S. Redruth, Cornwall.
1870. ‡Davidson, Alexander, M.D. 8 Peel-street, Toxteth Park, Liverpool.
1859. ‡Davidson, Charles. Grove House, Auchmull, Aberdeen.
1871.§§Davidson, James. Newbattle, Dalkeith, N.B.
1859. ‡Davidson, Patrick. Inchmarlo, near Aberdeen.
1872. ‡Davidson, Thomas, F.R.S., F.G.S. 3 Leopold-road, Brighton.
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1863. ‡*Davies, Griffith. 17 Cloudesley-street, Islington, London, N.*
1842. Davies-Colley, Dr. Thomas. Newton, near Chester.
1873. *Davis, Alfred. Sun Foundry, Leeds.
1870. *Davis, A. S. Mornington Villa, Leckhampton-road, Cheltenham.
1864. ‡Davis, Charles E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1873. *Davis, James W. Chevinedge, near Halifax.
1856. *Davis, Sir John Francis, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood, near Compton, Bristol.
1859. ‡Davis, J. Barnard, M.D., F.R.S., F.S.A. Shelton, Hanley, Staffordshire.
1859. *Davis, Richard, F.L.S. 9 St. Helen's-place, London, E.C.
1873. ‡Davis, William Samuel. 1 Cambridge Villas, Derby.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡Davy, Edmund W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. M. Bedford-circus, Exeter.
1854. *Dawbarn, William. Elmswood, Aigburth, Liverpool.
Dawes, John Samuel, F.G.S. Lappel Lodge, Quinton, near Birmingham.
1860. *Dawes, John T., jun. Llanferris, Mold, North Wales.
1864. ‡Dawkins, W. Boyd, M.A., F.R.S., F.G.S., F.S.A. Birchview, Norman-road, Rusholme, Manchester.
Dawson, John. Barley House, Exeter.
1855. ‡Dawson, John W., M.A., LL.D., F.R.S., F.G.S., Principal of M'Gill College, Montreal, Canada.
1859. *Dawson, Captain William G. Plumstead Common-road, Kent, S.E.
1871. ‡Day, St. John Vincent, C.E., F.R.S.E. 166 Buchanan-street, Glasgow.

Year of Election.

1870. §DEACON, G. F., M.I.C.E. Rock Ferry, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1859. ‡Dean, David. Banchory, Aberdeen.
1861. ‡Dean, Henry. Colne, Lancashire.
1870. *Deane, Rev. George, B.A., D.Sc., F.G.S. Spring Hill College, Moseley, near Birmingham.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S., Lecturer on Chemistry at Guy's Hospital, London, S.E.
1878. §Delany, Rev. William. St. Stanislaus College, Tullamore.
1854. *DE LA RUE, WARREN, M.A., D.C.L., Ph.D., F.R.S., F.C.S., F.R.A.S. 73 Portland-place, London, W.
1870. ‡De Meschin, Thomas, M.A., LL.D. 3 Middle Temple-lane, Temple, London, E.C.
Denchar, John. Morningside, Edinburgh.
1875. ‡Denny, William. Seven Ship-yard, Dumbarton.
Dent, William Yerbury. Royal Arsenal, Woolwich.
1870. *Denton, J. Bailey. 22 Whitehall-place, London, S.W.
1874. §DE RANCE, CHARLES E., F.G.S. 28 Jermyn-street, London, S.W.
1856. *DERBY, The Right Hon. the Earl of, LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.
1874. *Derham, Walter, M.A., LL.M., F.G.S. Henleaze Park, Westbury-on-Trym, Bristol.
1878. §De Rinzy, James Harward. Khelat Survey, Sukkur, India.
De Saumarez, Rev. Hailland, M.A. St. Peter's Rectory, Northampton.
1870. ‡Desmond, Dr. 44 Irvine-street, Edge Hill, Liverpool.
1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
DE TABLEY, GEORGE, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.
1869. ‡DEVON, The Right Hon. the Earl of, D.C.L. Powderham Castle, near Exeter.
*DEVONSHIRE, His Grace the Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.
1868. ‡DEWAR, JAMES, M.A., F.R.S., F.R.S.E., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural Experimental Philosophy in the University of Cambridge. Brookside, Cambridge.
1872. ‡Dewick, Rev. E. S. The College, Eastbourne, Sussex.
1873. *Dew-Smith, A. G. 7A Eaton-square, London, S.W.
1852. ‡DICKIE, GEORGE, M.A., M.D., F.L.S., Professor of Botany in the University of Aberdeen.
1864. *Dickinson, F. H., F.G.S. Kingweston, Somerton, Taunton; and 121 St. George's-square, London, S.W.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.
1867. ‡DICKSON, ALEXANDER, M.D., Professor of Botany in the University of Glasgow. 11 Royal-circus, Edinburgh.
1876. ‡Dickson, Gavin Irving. 37 West George-street, Glasgow.
1862. *DILKE, Sir CHARLES WENTWORTH, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.
1877. §Dillon, James, C.E. 46 Morehampton-road, Dublin.
1848. ‡DILLWYN, LEWIS LLEWELYN, M.P., F.L.S., F.G.S. Parkwerne, near Swansea.

Year of Election.

1872. §DINES, GEORGE. Woodside, Hersham, Walton-on-Thames.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1859. *Dingle, Rev. J. Lanchester Vicarage, Durham.
1876. ‡Ditchfield, Arthur. 12 Taviton-street, Gordon-square, London, W.C.
1868. ‡Dittmar, W. Andersonian University, Glasgow.
1874. *Dixon, A. E. Dunowen, Cliftonville, Belfast.
1853. ‡Dixon, Edward, M.I.C.E. Wilton House, Southampton.
1861. ‡DIXON, W. HEPWORTH, F.S.A., F.R.G.S. 6 St. James's-terrace, Regent's Park, London, N.W.
*Dobbin, Leonard, M.R.I.A. 27 Gardiner's-place, Dublin.
1851. ‡Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne Park, London, W.
1878. *DOBSON, G. E., M.A., M.B., F.L.S. Royal Victoria Hospital, Netley, Southampton.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
1875. *Docwra, George, jun. Grosvenor-road, Handsworth, Birmingham.
1870. *Dodd, John. 6 Thomas-street, Liverpool.
1876. ‡Dodds, J. M. 15 Sandyford-place, Glasgow.
*Dodsworth, Benjamin. Burton House, Scarborough.
*Dodsworth, George. The Mount, York.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. ‡Domvile, William C., F.Z.S. Thorn Hill, Bray, Dublin.
1867. ‡Don, John. The Lodge, Broughty Ferry, by Dundee.
1867. ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
1873. ‡Donham, Thomas. Huddersfield.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *Donkin, Bryan. May's Hill, Shortlands, Kent.
1874. ‡Donnell, Professor, M.A. 76 Stephen's-green South, Dublin.
1861. ‡Donnelly, Captain, R.E. South Kensington Museum, London, W.
1857. *DONNELLY, WILLIAM, C.B., Registrar-General for Ireland. Charlemont House, Dublin.
1857. ‡Donovan, M., M.R.I.A. Clare-street, Dublin.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. ‡Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1876. *Douglas, Rev. G. C. M. 10 Fitzroy-place, Glasgow.
1877. *Douglass, James N., C.E. Trinity House, London, E.C.
1878. §Douglass, William. 104 Baggot-street, Dublin.
1855. ‡DOVE, HECTOR. Rose Cottage, Trinity, near Edinburgh.
1870. ‡Dowie, J. M. Wetstones, West Kirby, Cheshire.
1876. §Dowie, Mrs. Muir. Wetstones, West Kirby, Cheshire.
1878. §Dowling, Thomas. Clonbrock Lodge, Rathgar, Dublin.
1857. ‡DOWNING, S., C.E., LL.D., Professor of Civil Engineering in the University of Dublin. 4 The Hill, Monkstown, Co. Dublin.
1878. §Dowse, The Right Hon. Baron. 38 Mountjoy-square, Dublin.
1872. *Dowson, Edward, M.D. 117 Park-street, London, W.
1865. *Dowson, E. Theodore. Geldeston, near Beccles, Suffolk.
1868. §§DRESSER, HENRY E., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1873. §Drew, Frederic, F.G.S., F.R.G.S. Eton College, Windsor.
1869. §Drew, Joseph, LL.D., F.R.A.S., F.G.S. Weymouth.
1865. ‡Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Manchester.
1872. *Druce, Frederick. 27 Oriental-place, Brighton.
1874. ‡Druitt, Charles. Hampden-terrace, Rugby-road, Belfast.
1859. ‡*Drummond, Robert.* 17 *Stratton-street, London, W.*

Year of Election.

1866. *Dry, Thomas. 23 Gloucester-road, Regent's Park, London, N.W.
1870. §Drysdale, J. J., M.D. 36A Rodney-street, Liverpool.
1856. *DUCIE, The Right. Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Holmfield House, Grassendale, Liverpool.
1867. *DUFF, MOUNTSTUART ELPHINSTONE GRANT-, LL.B., M.P. York House, Twickenham, Middlesex.
1852. ‡Dufferin and Clandeboye, The Right Hon. the Earl of, K.P., K.C.B., F.R.S. Clandeboye, near Belfast, Ireland.
1877. §Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. §Duffin, W. E. L'Estrange, C.E. Waterford.
1859. *Duncan, Alexander. 7 Prince's-gate, London, S.W.
1859. ‡Duncan, Charles. 52 Union-place, Aberdeen.
1866. *Duncan, James. 71 Cromwell-road, South Kensington, London, W.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1871. ‡Duncan, James Matthew, M.D. 30 Charlotte-square, Edinburgh.
1867. ‡DUNCAN, PETER MARTIN, M.B., F.R.S., F.G.S., Professor of Geology in King's College, London. 99 Abbey-road, St. John's Wood, London, N.W.
Dunlop, Alexander. Clober, Milngavie, near Glasgow.
1853. *Dunlop, William Henry. Annanhill, Kilmarnock, Ayrshire.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1876. *Dunn, James. 64 Robertson-street, Glasgow.
1862.§§DUNN, ROBERT, F.R.C.S. 31 Norfolk-street, Strand, London, W.C.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. §Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
Dunnington-Jefferson, Rev. Joseph, M.A., F.C.P.S. Thicket Hall, York.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1866. ‡Duprey, Perry. Woodbury Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡DURHAM, ARTHUR EDWARD, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
Dykes, Robert. Kilmorie, Torquay, Devon.
1869. §Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868. ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1861. ‡Eadson, Richard. 13 Hyde-road, Manchester.
1877.§§Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
*EARNSHAW, Rev. SAMUEL, M.A. 14 Broomfield, Sheffield.
1874. §Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1871. *EASTON, EDWARD, C.E. 7 Delahay-street, Westminster, S.W.
1863. §Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John, C.E. Durie House, Abercromby-street, Helensburgh, N.B.
1870. §Eaton, Richard. Basford, Nottingham.
Ebden, Rev. James Collett, M.A., F.R.A.S. Great Stukeley Vicarage, Huntingdonshire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. Martinstown, Dorchester.
1870. *Eddison, Dr. John Edwin. 29 Park-square, Leeds.

Year of Election.

*Eddy, James Ray, F.G.S. Carleton Grange, Skipton.
Eden, Thomas. Talbot-road, Oxton.
*EDGEWORTH, MICHAEL P., F.L.S., F.R.A.S. Mastrim House, Anerley, London, S.E.
1855. ‡Edmiston, Robert. Elmbank-crescent, Glasgow.
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 72 Portsdown-road, London, W.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. ‡Edward, Charles. Chambers, 8 Bank-street, Dundee.
1867. ‡Edward, James. Balruddery, Dundee.
1855. *EDWARDS, Professor J. BAKER, Ph.D., D.C.L. Montreal, Canada.
1867. ‡Edwards, William. 70 Princes-street, Dundee.
*EGERTON, Sir PHILIP DE MALPAS GREY, Bart., M.P., F.R.S., F.G.S. Oulton Park, Tarporley, Cheshire.
1859. *Eisdale, David A., M.A. 38 Dublin-street, Edinburgh.
1873. ‡Elcock, Charles. 39 Lyme-street, Shakspere-street, Ardwick, Manchester.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. St. Mary, Bedford.
Ellacombe, Rev. H. T., F.S.A. Clyst St. George, Topsham, Devon.
1863. ‡Ellenberger, J. L. Worksop.
1855. §Elliot, Robert, F.B.S.E. Wolfelee, Hawick, N.B.
1861. *ELLIOT, Sir WALTER, K.C.S.I., F.R.S., F.L.S. Wolfelee, Hawick, N.B.
1864. ‡Elliott, E. B. Washington, United States.
1872. ‡Elliott, Rev. E. B. 11 Sussex-square, Kemp Town, Brighton.
Elliott, John Fogg. Elvet Hill, Durham.
1864. *ELLIS, ALEXANDER JOHN, B.A., F.R.S., F.S.A. 25 Argyll-road, Kensington, London, W.
1877. §§Ellis, Arthur Devonshire. School of Mines, Jermyn-street, London, S.W.; and Thurnscoe Hall, Rotherham, Yorkshire.
1875. *Ellis, H. D. Fair Park House, Exeter.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1864. ‡Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.
*Ellis, Rev. Robert, A.M. The Institute, St. Saviour's Gate, York.
1869. ‡Ellis, William Horton. Pennsylvania, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1862. ‡Elphinstone, H. W., M.A., F.L.S. Cadogan-place, London, S.W.
1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.
1863. ‡Emery, Rev. W., B.D. Corpus Christi College, Cambridge.
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1866. ‡Enfield, William. Low Pavement, Nottingham.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. ‡English, J. T. Stratton, Cornwall.
ENNISKILLEN, The Right Hon. WILLIAM WILLOUGHBY, Earl of, LL.D., D.C.L., F.R.S., F.G.S., M.R.I.A. 65 Eaton-place, London, S.W.; and Florence Court, Fermanagh, Ireland.
1869. *Enys, John Davis. Care of F. G. Enys, Esq., Enys, Penryn, Cornwall.
1844. ‡Erichsen, John Eric, F.R.S., F.R.C.S., Professor of Clinical Surgery in University College, London. 6 Cavendish-place, London, W.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.

Year of Election.

1862. *Esson, William, M.A., F.R.S., F.C.S., F.R.A.S. Merton College; and 1 Bradmore-road, Oxford.

1878. §Estcourt, Charles, F.C.S. 8 St. James's-square, John Dalton-street, Manchester.

Estcourt, Rev. W. J. B. Long Newton, Tetbury.

1869. ‡Etheridge, Robert, F.R.S.L. & E., F.G.S., Palæontologist to the Geological Survey of Great Britain. Museum of Practical Geology, Jermyn-street; and 19 Halsey-street, Cadogan-place, London, S.W.

1870. *Evans, Arthur John, F.S.A. Nash Mills, Hemel Hempsted.

1865. *Evans, Rev. Charles, M.A. The Rectory, Solihull, Birmingham.

1872. *Evans, Frederick J., C.E. Claypoonds, Brentford, Middlesex, W.

1876. ‡Evans, Captain Frederick J. O., C.B., R.N., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty. 116 Victoria-street, Westminster, S.W.

1869. *Evans, H. Saville W. Wimbledon Park House, Wimbledon, S.W.

1861. *Evans, John, D.C.L., F.R.S., F.S.A., F.G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempsted.

1876. ‡Evans, Mortimer, C.E. 97 West Regent-street, Glasgow.

1865. ‡Evans, Sebastian, M.A., LL.D. Highgate, near Birmingham.

1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.

1866. ‡Evans, Thomas, F.G.S. Belper, Derbyshire.

1865. *Evans, William. Ellerslie, Augustus-road, Edgbaston, Birmingham.

1871. §§Eve, H. W. Wellington College, Wokingham, Berkshire.

1868. *Everett. J. D., D.C.L., F.R.S.E., Professor of Natural Philosophy in Queen's College, Belfast. Rushmere, Malone-road, Belfast.

1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.

1874. ‡Ewart. William. Glenmachan, Belfast.

1874. ‡Ewart, W. Quartus. Glenmachan, Belfast.

1859. *Ewing, Archibald Orr, M.P. Ballikinrain Castle, Killearn, Stirlingshire.

1876. *Ewing, James Alfred, B.Sc., F.R.S.E., Professor of Mechanical Engineering in the University of Tokio, Japan. 12 Laurel Bank, Dundee.

1871. *Exley, John T., M.A. 1 Cotham-road. Bristol.

1846. *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, London, S.W.; and Warrens, near Lyndhurst, Hants.

1866. ‡Eyre, Major-General Sir Vincent, F.R.G.S. Athenæum Club, Pall Mall, London, S.W.

Eyton, Charles. Hendred House, Abingdon.

1849. ‡Eyton, T. C. Eyton, near Wellington, Salop.

1842. *Fairbairn, Thomas. Manchester.*

1865. ‡Fairley, Thomas, F.R.S.E. 8 Newington-grove, Leeds.

1876. ‡Fairlie, James M. Charing Cross Corner, Glasgow.

1870. ‡Fairlie, Robert, C.E. Woodlands, Clapham Common, London, S.W.

1864. ‡Falkner, F. H. Lyncombe, Bath.

1877. §Faraday, F. J., F.S.S. College Chambers, 17 Brazenose-street, Manchester.

1859. ‡Farquharson, Robert O. Houghton, Aberdeen.

1861. §Farr, William, M.D., D.C.L., F.R.S., Superintendent of the Statistical Department, General Register Office, London. Southlands, Bickley, Kent.

1866. *Farrar, Rev. Frederick William, M.A., D.D., F.R.S., Canon of Westminster. St. Margaret's Rectory, Westminster, S.W.

1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.

Year of Election.

1869. *Faulding, Joseph. The Grange, Greenhill Park, New Barnet, Herts.
1869. ‡Faulding, W. F. Didsbury College, Manchester.
1859. *FAWCETT, HENRY, M.A., M.P., Professor of Political Economy in the University of Cambridge. 51 The Lawn, South Lambeth-road, London, S.W.; and 8 Trumpington-street, Cambridge.
1863. ‡Fawcus, George. Alma-place, North Shields.
1873. *Fazakerley, Miss. The Castle, Denbigh.
1845. ‡Felkin, William, F.L.S. The Park, Nottingham.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1864. §§FELLOWS, FRANK P., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square; and Keswick, near Belfast.
1876. *Fergus, Andrew, M.D. 3 Elmbank-crescent, Glasgow.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1859. ‡Ferguson, John. Cove, Nigg, Inverness.
1871. *Ferguson, John, M.A., Professor of Chemistry in the University of Glasgow.
1867. ‡Ferguson, Robert M., Ph D., F.R.S.E. 8 Queen-street, Edinburgh.
1857. ‡Ferguson, Samuel, LL.D., Q.C. 20 Great George's-street North, Dublin.
1854. ‡Ferguson, William, F.L.S., F.G.S. Kinmundy, near Mintlaw, Aberdeenshire.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1863. *FERNIE, JOHN. Bonchurch, Isle of Wight.
1862. ‡FERRERS, Rev. NORMAN MACLEOD, M.A., F.R.S. Caius College, Cambridge.
1873. ‡Ferrier, David, M.A., M.D., F.R.S., Professor of Forensic Medicine in King's College. 16 Upper Berkeley-street, London, W.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1869. *FIELD, ROGERS, B.A., C.E. 5 Cannon-row, Westminster, S.W.
1876. ‡Fielden, James. 2 Darnley-street, Pollokshields, near Glasgow.
1864. ‡Finch, Frederick George, B.A., F.G.S. 21 Croom's-hill, Greenwich, S.E.
Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1878. *Findlater, William. 2 Fitzwilliam-square, Dublin.
1868. ‡Firth, G. W. W. St. Giles's-street, Norwich.
Firth, Thomas. Northwick.
1863. *Firth, William. Burley Wood, near Leeds.
1851. *FISCHER, WILLIAM L. F., M.A., LL.D., F.R.S. St. Andrews, Scotland.
1858. ‡Fishbourne, Captain E. G., R.N. 6 Welamere-terrace, Paddington, London, W.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlston Rectory, near Cambridge.
1873. §Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1875. *Fisher, W. W., M.A., F.C.S. 2 Park-crescent, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1871. *Fison, Frederick W., F.C.S. Eastmoor, Ilkley, Yorkshire.
1871. ‡FITCH, J. G., M.A. 5 Lancaster-terrace, Regent's Park, London, N.W.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1878. §Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §Fitzgerald, George Francis. Trinity College, Dublin.
1857. ‡Fitzgerald, The Right Hon. Lord Otho. 13 Dominick-street, Dublin.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Baggot-street, Dublin.

Year of Election.

1865. ‡Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.
Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood, Lancashire.
1850. ‡Fleming, Professor Alexander, M.D. 121 Hagley-road, Birmingham.
Fleming, Christopher, M.D. Merrion-square North, Dublin.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
Fleming, John G., M.D. 155 Bath-street, Glasgow.
1876. ‡Fleming, Sandford. Ottawa, Canada.
*FLEMING, WILLIAM, M.D. Rowton Grange, near Chester.
1867. §FLETCHER, ALFRED E. 5 Edge-lane, Liverpool.
1870. ‡Fletcher, B. Edgington. Norwich.
1853. ‡FLETCHER, ISAAC, M.P., F.R.S., F.R.A.S., F.G.S. Tarn Bank, Workington.
1869. ‡FLETCHER, LAVINGTON E., C.E. 41 Corporation-street, Manchester.
Fletcher, T. B. E., M.D. 7 Waterloo-street, Birmingham.
1862. ‡FLOWER, WILLIAM HENRY, F.R.S., F.L.S., F.G.S., F.R.C.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons. Royal College of Surgeons, Lincoln's-Inn-fields, London, W.C.
1877. *Floyer, Ernest A., F.R.G.S. 7 The Terrace, Putney, S.W.
1867. ‡Foggie, William. Woodville, Maryfield, Dundee.
1873. *Forbes, Professor George, M.A., F.R.S.E. Andersonian University, Glasgow.
1855. ‡Forbes, Rev. John. Symington Manse, Biggar, Scotland.
1877. §Forbes, W. A. West Wickham, Kent.
Ford, H. R. Morecombe Lodge, Yealand Conyers, Lancashire.
1866. ‡Ford, William. Hartsdown Villa, Kensington Park-gardens East, London, W.
1875. *FORDHAM, H. GEORGE, F.G.S. Odsey, near Royston, Herts.
*Forrest, William Hutton. 1 Pitt-terrace, Stirling.
1867. ‡Forster, Anthony. Finlay House, St. Leonard's-on-Sea.
1858. *FORSTER, The Right Hon. WILLIAM EDWARD, M.P., F.R.S. 80 Eccleston-square, London, S.W.; and Wharfeside, Burley-in-Wharfedale, Leeds.
1854. *Fort, Richard. Read Hall, Whalley, Lancashire.
1877. §§FORTESCUE, The Right Hon. the Earl. Castle Hill, North Devon.
1870. ‡Forwood, William B. Hopeton House, Seaforth, Liverpool.
1875. ‡Foster, A. Le Neve. East Hill, Wandsworth, Surrey, S.W.
1865. ‡Foster, Balthazar, M.D., Professor of Medicine in Queen's College, Birmingham. 16 Temple-row, Birmingham.
1865. *FOSTER, CLEMENT LE NEVE, B.A., D.Sc., F.G.S. Truro, Cornwall.
1857. *FOSTER, GEORGE CAREY, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 12 Hilldrop-road, London, N.
*Foster, Rev. John, M.A. The Oaks Vicarage, Loughborough.
1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.
1877. §Foster, Joseph B. 6 James-street, Plymouth.
1859. *FOSTER, MICHAEL, M.A., M.D., F.R.S., F.L.S., F.C.S. Trinity College, and Great Shelford, near Cambridge.
1859. §FOSTER, PETER LE NEVE, M.A. Society of Arts, Adelphi, London, W.C.
1873. ‡Foster, Peter Le Neve, jun. Society of Arts, Adelphi, London, W.C.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1859. *Foster, S. Lloyd. Old Park Hall, Walsall, Staffordshire.
1873. *Foster, William. Harrowins House, Queensbury, Yorkshire.

Year of Election.

1842. *Fothergill, Benjamin.* 10 *The Grove, Boltons, West Brompton, London, S.W.*
1870. ‡Foulger, Edward. 55 Kirkdale-road, Liverpool.
1866.§§Fowler, George, M.I.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1876. §Fowler, John. 4 Gray-street, Glasgow.
1870. *Fowler, Robert Nicholas, M.A., F.R.G.S. 50 Cornhill, London, E.C.
1868. ‡Fox, Major-General A. H. LANE, F.R.S., F.G.S., F.R.G.S., F.S.A. Guildford, Surrey.
*Fox, Rev. Edward, M.A. Upper Heyford, Banbury.
1876.§§Fox, G. S. Lane. 9 Sussex-place, London, S.W.
*Fox, Joseph Hayland. The Cleve, Wellington, Somerset.
1860. ‡Fox, Joseph John. Church-row, Stoke Newington, London, N.
1866. *Francis, G. B. Inglesby House, Stoke Newington-green, London, N.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and Manor House, Richmond, Surrey.
1846. ‡FRANKLAND, EDWARD, D.C.L., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Royal School of Mines. 14 Lancaster-gate, London, W.
*Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James. 25 Westland-row, Dublin.
Fraser, James William. 8A Kensington Palace-gardens, London, W.
1865. *FRASER, JOHN, M.A., M.D. Chapel Ash, Wolverhampton.
1871. ‡FRASER, THOMAS R., M.D., F.R.S. L. & E. 3 Grosvenor-street, Edinburgh.
1876. ‡Fraser, Rev. William, LL.D. Free Middle Manse, Paisley.
1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester, Sussex.
1877.§§Freeman, Francis Ford. Blackfriars House, Plymouth.
1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
Frere, George Edward, F.R.S. Roydon Hall, Diss, Norfolk.
1869. ‡FRERE, The Right Hon. Sir H. BARTLE E., Bart., G.C.S.I., G.C.B., F.R.S., F.R.G.S., Governor of Cape Colony and Dependencies. Government House, Cape Town.
1869. ‡Frere, Rev. William Edward. The Rectory, Bilton, near Bristol.
1857. *Frith, Richard Hastings, C.E., M.R.I.A., F.R.G.S.I. 48 Summer-hill, Dublin.
1869. ‡Frodsham, Charles. 26 Upper Bedford-place, Russell-square, London, W.C.
1847. ‡Frost, William. Wentworth Lodge, Upper Tulse Hill, London, S.W.
1860. *FROUDE, WILLIAM, M.A., C.E., F.R.S. Chelston Cross, Torquay.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
Fry, Francis. Cotham, Bristol.
1875. *Fry, Joseph Storrs. 2 Charlotte-street, Bristol.
Fry, Richard. Cotham Lawn, Bristol.
1872. *Fuller, Rev. A. Pallant, Chichester.
1873. ‡*Fuller, Claude S., R.N.* 44 *Holland-road, Kensington, London, W.*
1859. ‡FULLER, FREDERICK, M.A., Professor of Mathematics in the University and King's College, Aberdeen.
1869. ‡FULLER, GEORGE, C.E., Professor of Engineering in Queen's College, Belfast. 6 College-gardens, Belfast.
1864. *Furneaux, Rev. Alan. St. German's Parsonage, Cornwall.

Year of Election.

*Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡GAGES, ALPHONSE, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Richmond Hill, Sheffield.
1876. ‡Gairdner, Charles. Mount Vernon, Shettleston, N.B.
1850. ‡Gairdner, Professor W. T., M.D. 225 St. Vincent-street, Glasgow.
1861. ‡Galbraith, Andrew. Glasgow.
GALBRAITH, Rev. J. A., M.A., M.R.I.A. Trinity College, Dublin.
1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 338 Oxford-street, London, W.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
1875. §Galloway, W., H.M. Inspector of Mines. Cardiff.
1860. *GALTON, Captain DOUGLAS, C.B., D.C.L., F.R.S., F.L.S., F.G.S., F.R.G.S. (GENERAL SECRETARY.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *GALTON, FRANCIS, M.A., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. 13 Margaret-street, Cavendish-square, London, W.
1870. §Gamble, Lieut.-Colonel D. St. Helen's, Lancashire.
1870. ‡Gamble, J. C. St. Helen's, Lancashire.
1872. *Gamble, John G., M.A. 10 Vyvyan-terrace, Clifton, Bristol; and Albion House, Rottingdean, Brighton.
1877. §§Gamble, William. St. Helen's, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S., F.R.S.E., Professor of Physiology in Owens College, Manchester. Fairview, Princes-road, Fallowfield, Manchester.
1862. §GARNER, ROBERT, F.L.S. Stoke-upon-Trent.
1865. §Garner, Mrs. Robert. Stoke-upon-Trent.
1842. Garnett, Jeremiah. Warren-street, Manchester.
1873. ‡Garnham, John. 123 Bunhill-row, London, E.C.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Mayfield-road, Grassendale, Liverpool.
1847. *Gaskell, Samuel. Windham Club, St. James's-square, London, S.W.
1842. Gaskell, Rev. William, M.A. Plymouth-grove, Manchester.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Park, East Grinstead, Sussex.
1875. §Gavey, J. 43 Stacey-road, Routh, Cardiff.
1875. §Gaye, Henry S. Newton Abbott, Devon.
1873. ‡Geach, R. G. Cragg Wood, Rawdon, Yorkshire.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1859. ‡Geddes, William D., M.A., Professor of Greek, King's College, Old Aberdeen.
1854. ‡Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1867. §§GEIKIE, ARCHIBALD, LL.D., F.R.S. L. & E., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh; and Boroughfield, Edinburgh.
1871. §Geikie, James, F.R.S. L. & E., F.G.S. 16 Duncan-terrace, Newington, Edinburgh.
1855. ‡*Gemmell, Andrew. 38 Queen-street, Glasgow.*
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1854. ‡*Gerard, Henry. 8A Rumford-place, Liverpool.*
1870. ‡Gerstl, R. University College, London, W.C.
1870. *Gervis, Walter S., M.D., F.R.G.S. Ashburton, Devonshire.

Year of Election.

1856. *Gething, George Barkley. Springfield, Newport, Monmouthshire.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1871. ‡Gibson, Alexander. 10 Albany-street, Edinburgh.
1868. ‡Gibson, C. M. Bethel-street, Norwich.
1874. ‡Gibson, Edward, Q.C. 23 Fitzwilliam-square, Dublin.
1876. *Gibson, George Alexander, M.B., D.Sc., F.G.S. 10 Old-square, Birmingham.
*Gibson, George Stacey. Saffron Walden, Essex.
1852. ‡Gibson, James, M.A., Q.C. 35 Mountjoy-square South, Dublin.
1870. ‡Gibson, Thomas. 51 Oxford-street, Liverpool.
1870. ‡Gibson, Thomas, jun. 10 Parkfield-road, Prince's Park, Liverpool.
1842. GILBERT, JOSEPH HENRY, Ph.D., F.R.S., F.C.S. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1859. *Gilchrist, James, M.D. Crichton House, Dumfries.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
1878. §Giles, Oliver. 16 Bellevue-crescent, Clifton, Bristol.
Giles, Rev. William. Netherleigh House, near Chester.
1878. §Gill, Rev. A. W. H. 44 Eaton-square, London, S.W.
1871. *GILL, DAVID, jun. 36 Pembroke-road, Kensington, London, W.
1868. ‡Gill, Joseph. Palermo, Sicily. (Care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.)
1864. ‡GILL, THOMAS. 4 Sydney-place, Bath.
1861. *Gilroy, George. Hindley Hall, Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1876. §Gimingham, Charles H. 45 St. Augustine's-road, Camden-square, London, N.W.
1867.§§GINSBURG, Rev. C. D., D.C.L., LL.D. Wokingham, Berkshire.
1869. ‡Girdlestone, Rev. Canon E., M.A. Halberton Vicarage, Tiverton.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1850. *Gladstone, George, F.C.S., F.R.G.S. 31 Ventnor-villas, Cliftonville, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, Hyde Park, London, W.
1861. **Gladstone, Murray. 35 Wilton-crescent, London, S.W.*
1875. *Glaisher, Ernest Henry. 1 Dartmouth-place, Blackheath, London, S.E.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, London, S.E.
1871. *GLAISHER, J. W. L., M.A., F.R.S., F.R.A.S. Trinity College, Cambridge.
1853. ‡Gleadon, Thomas Ward. Moira-buildings, Hull.
1870. §Glen, David Corse, F.G.S. 14 Annfield-place, Glasgow.
1859. ‡Glennie, J. S. Stuart. 6 Stone-buildings, Lincoln's Inn, London, W.C.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1874. §Glover, George T. 30 Donegall-place, Belfast.
Glover, Thomas. Becley Old Hall, Rowsley, Bakewell.
1874. ‡Glover, Thomas. 77 Claverton-street, London, S.W.
1870. ‡Glynn, Thomas R. 1 Rodney-street, Liverpool.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1878. *Godlee, J. Lister. 3 New-square, Lincoln's Inn, London, W.C.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1846. ‡GODWIN-AUSTEN, ROBERT A. C., B.A., F.R.S., F.G.S. Shalford House, Guildford.

Year of Election.

1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1877. §GOFF, JAMES. The Mansion House, Dublin.
1873.§§Goldthorp, Miss R. F. C Cleckheaton, Bradford, Yorkshire.
1878. §Good, Rev. Thomas, B.D. 51 Wellington-road, Dublin.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1870. ‡Goodison, George William, C.E. Gateacre, Liverpool.
1842. *GOODMAN, JOHN, M.D. 8 Leicester-street, Southport.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869. ‡Goodman, Neville. Peterhouse, Cambridge.
1870. *Goodwin, Rev. Henry Albert, M.A., F.R.A.S. Lambourne Rectory, Romford.
1878. §GORDON, J. E. H., B.A. (ASSISTANT SECRETARY.) Holmwood Cottage, Dorking.
1871. *Gordon, Joseph Gordon, F.C.S. 20 King-street, St. James's, London, S.W.
1840. ‡Gordon, Lewis D. B. Totteridge, Whetstone, London, N.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1865. ‡Gore, George, LL.D., F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1870. ‡Gossage, William. Winwood, Woolton, Liverpool.
1875. *Gotch, Francis. Stokes Croft, Bristol.
*Gotch, Rev. Frederick William, LL.D. Stokes Croft, Bristol.
*Gotch, Thomas Henry. Kettering.
1873. §Gott, Charles, M.I.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Right Hon. George S., Viscount, M.A., F.L.S., F.G.S. St. Helen's, Booterstown, Dublin.
1868. ‡Gould, Rev. George. Unthank-road, Norwich.
GOULD, JOHN, F.R.S., F.L.S., F.R.G.S., F.Z.S. 26 Charlotte-street, Bedford-square, London, W.C.
1873. ‡Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford, Yorkshire.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. §Gow, Robert. Cairndowan, Dowanhill, Glasgow.
Gowland, James. London-wall, London, E.C.
1873. §Goyder, Dr. D. Manville-crescent, Bradford, Yorkshire.
1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.
1867. *GRAHAM, CYRIL, F.L.S., F.R.G.S. 9 Cleveland-row, St. James's, London, S.W.
1875. ‡GRAHAME, JAMES. Auldhouse, Pollokshaws, near Glasgow.
1852. *Grainger, Rev. John, D.D., M.R.I.A. Skerry and Rathcavan Rectory, Broughshane, near Ballymena, Co. Antrim.
1871. ‡GRANT, Sir ALEXANDER, Bart., M.A., Principal of the University of Edinburgh. 21 Lansdowne-crescent, Edinburgh.
1870.§§GRANT, Colonel J. A., C.B., C.S.I., F.R.S., F.L.S., F.R.G.S. 19 Upper Grosvenor-street, London, W.
1859. ‡Grant, Hon. James. Cluny Cottage, Forres.
1855. *GRANT, ROBERT, M.A., LL.D., F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.
1854. ‡GRANTHAM, RICHARD B., C.B., F.G.S. 22 Whitehall-place, London, S.W.
1864. ‡Grantham, Richard F. 22 Whitehall-place, London, S.W.
1874. ‡Graves, Rev. James, B.A., M.R.I.A. Inisnag Glebe, Stonyford, Co. Kilkenny.
*Graves, Rev. Richard Hastings, D.D. 31 Raglan-road, Dublin.
1864. *Gray, Rev. Charles. The Vicarage, Blyth, Worksop.

Year of Election.

1865. ‡Gray, Charles. Swan-bank, Bilston.
1870. ‡Gray, C. B. 5 Rumford-place, Liverpool.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1857. ‡Gray, Sir John, M.D. Rathgar, Dublin.
1864. ‡Gray, Jonathan. Summerhill House, Bath.
1859. ‡Gray, Rev. J. H. Bolsover Castle, Derbyshire.
1870. §Gray, J. Macfarlane. 127 Queen's-road, Peckham, London, S.E.
1878. §Gray, Matthew Hamilton. 14 St. John's Park, Blackheath, London, S.E.
1878. §Gray, Robert Kaye. 14 St. John's Park, Blackheath, London, S.E.
1873. ‡Gray, William, M.R.I.A. 6 Mount Charles, Belfast.
*GRAY, WILLIAM, F.G.S. Gray's-court, Minster Yard, York.
*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1854. *Grazebrook, Henry. Clent Grove, near Stourbridge, Worcestershire.
1866. §Greaves, Charles Augustus, M.B., LL.B. 32 Friar-gate, Derby.
1873. ‡Greaves, James H., C.E. Albert-buildings, Queen Victoria-street, London, E.C.
1869. §Greaves, William. Wellington-circus, Nottingham.
1872. §Greaves, William. 11 John-street, Bedford-row, London, W.C.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1875. ‡Greenwood, Frederick. School of Medicine, Leeds.
1877. §Greenwood, Holmes. 78 King-street, Accrington.
1862. *Greenwood, Henry. 32 Castle-street, and the Woodlands, Anfield-road, Anfield, Liverpool.
1849. ‡Greenwood, William. Stones, Todmorden.
1861. *GREG, ROBERT PHILIPS, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1833. Gregg, T. H. 22 Ironmonger-lane, Cheapside, London, E.C.
1860. ‡GREGOR, Rev. WALTER, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Charles Hutton, C.E. 1 Delahay-street, Westminster, S.W.
1861. §Gregson, Samuel Leigh. Aigburth-road, Liverpool.
1875. ‡Grenfell, J. Granville, B.A., F.G.S. 5 Albert-villas, Clifton, Bristol.
*GRESWELL, Rev. RICHARD, M.A., F.R.S., F.R.G.S. 39 St. Giles's-street, Oxford.
1869. ‡GREY, Sir GEORGE, F.R.G.S. Belgrave-mansions, Grosvenor-gardens, London, S.W.
1875. ‡Grey, Mrs. Maria G. 18 Cadogan-place, London, S.W.
1871. *Grierson, Samuel. Medical Superintendent of the District Asylum, Melrose, N.B.
1859. ‡GRIERSON, THOMAS BOYLE, M.D. Thornhill, Dumfriesshire.
1875. §Grieve, David, F.R.S.E. Hobart House, Dalkeith.
1870. ‡Grieve, John, M.D. 21 Lynedock-street, Glasgow.
1878. §Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
Griffith, Rev. C. T., D.D. Elm, near Frome, Somerset.
1859. *GRIFFITH, GEORGE, M.A., F.C.S. Harrow.
Griffith, George R. Fitzwilliam-place, Dublin.
1868. ‡GRIFFITH, Rev. JOHN, M.A., D.C.L. Findon Rectory, Worthing, Sussex.
1870. ‡Griffith, N. R. The Coppa, Mold, North Wales.
1870. ‡Griffith, Rev. Henry, F.G.S. Barnet, Herts.
1847. ‡Griffith, Thomas. Bradford-street, Birmingham.
GRIFFITHS, Rev. JOHN, M.A. Wadham College, Oxford.

Year of
Election.

1875. ‡Grignon, James, H.M. Consul at Riga. Riga.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1842. Grimshaw, Samuel, M.A. Errwod, Buxton.
1864. ‡GROOM-NAPIER, CHARLES OTTLEY, F.G.S. 18 Elgin-road, St. Peter's Park. London, N.W.
1869. §Grote, Arthur, F.L.S., F.G.S. 20 Cork-street, Burlington-gardens, London, W.
GROVE, The Hon. Sir WILLIAM ROBERT, Knt., M.A., Ph.D., F.R.S. 115 Harley-street, London, W.
1863. *GROVES, THOMAS B., F.C.S. 80 St. Mary-street, Weymouth.
1869. ‡GRUBB, HOWARD, F.R.A.S. 40 Leinster-square, Rathmines, Dublin.
1872. ‡Grüneisen, Charles Lewis, F.R.G.S. 16 Surrey-street, Strand, London, W.C.
Guest, Edwin, M.A., LL.D., F.R.S., Master of Caius College, Cambridge. Caius Lodge, Cambridge; and Sandford Park, Oxfordshire.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1856. *GUISE, Sir WILLIAM VERNON, Bart., F.G.S., F.L.S. Elmore Court, near Gloucester.
1862. ‡Gunn, John, M.A., F.G.S. Irstedd Rectory, Norwich.
1877. §Gunn, William, F.G.S. Barnard Castle, Darlington.
1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., Keeper of the Zoological Collections in the British Museum. British Museum, London, W.C.
1868. *Gurney, John. Sprouston Hall, Norwich.
1860. *GURNEY, SAMUEL, F.L.S., F.R.G.S. 29 Hanover-terrace, Regent's Park, London, N.W.
*Gutch, John James. Holgate Lodge, York.
1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1859. ‡GUTHRIE, FREDERICK, B.A., F.R.S. L. & E., Professor of Physics in the Royal School of Mines. 24 Stanley-crescent, Notting Hill, London, W.
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡Gwyther, R. F. Owens College, Manchester.

Hackett, Michael. Brooklawn, Chapelizod, Dublin.
1865. ‡Hackney, William. 9 Victoria-chambers, Victoria-street, London, S.W.
1866. *Hadden, Frederick J. 3 Park-terrace, Nottingham.
1866. ‡Haddon. Henry. Lenton Field, Nottingham.
Haden, G. N. Trowbridge, Wiltshire.
1842. Hadfield, George. Victoria-park, Manchester.
1870. ‡Hadivan, Isaac. 3 Huskisson-street, Liverpool.
1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.
1870. ‡Haigh, George. Waterloo, Liverpool.
*Hailstone, Edward, F.S.A. Walton Hall, Wakefield, Yorkshire.
1869. ‡Hake, R. C. Grasmere Lodge, Addison-road, Kensington, London, W.
1875. §§Hale, Rev. Edward, M.A., F.G.S., F.R.G.S. Eton College, Windsor.
1870. ‡Halhead, W. B. 7 Parkfield-road, Liverpool.
HALIFAX, The Right Hon. Viscount. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.
1872. ‡Hall, Dr. Alfred. 30 Old Steine, Brighton.
1854. *HALL, HUGH FERGIE, F.G.S. Greenheys, Wallasey, Birkenhead.

Year of Election.

1859. ‡Hall, John Frederic. Ellerker House, Richmond, Surrey.
1872. *Hall, Captain Marshall. Scientific Club, Savile-row, London, W.
*Hall, Thomas B. Australia. (Care of J. P. Hall, Esq., Crane House, Great Yarmouth.)
1866. *HALL, TOWNSHEND M., F.G.S. Pilton, Barnstaple.
1860. §Hall, Walter. 11 Pier-road, Erith.
1873. §HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1868. *HALLETT, WILLIAM HENRY, F.L.S. Buckingham House, Marine Parade, Brighton.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. The Leys, Barrow-on-Soar, near Loughborough.
1866. §HAMILTON, ARCHIBALD, F.G.S. South Barrow, Bromley, Kent.
1865. §§Hamilton, Gilbert. Leicester House, Kenilworth-road, Leamington.
HAMILTON, The Very Rev. HENRY PARR, Dean of Salisbury, M.A., F.R.S. L. & E., F.G.S., F.R.A.S. Salisbury.
1869. ‡Hamilton, John, F.G.S. Fyne Court, Bridgewater.
1869. §Hamilton, Roland. Oriental Club, Hanover-square, London, W.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1878. §Hanagan, Anthony. Luckington, Dalkey.
1878. §Hance, Edward M. 24 Church-road, Wavertree, Liverpool.
1875. ‡Hancock, C. F., jun., M.A. Royal Institution, Albemarle-street, London, W.
1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1850. ‡Hancock, John, J.P. The Manor House, Lurgan, Co. Armagh.
1861. ‡Hancock, Walker. 10 Upper Chadwell-street, Pentonville, London, N.
1857. ‡Hancock, William J. 23 Synnot-place, Dublin.
1847. ‡HANCOCK, W. NEILSON, LL.D., M.R.I.A. 64 Upper Gardiner-street, Dublin.
1876. §Hancock, Mrs. W. Neilson. 64 Upper Gardiner-street, Dublin.
1865. ‡Hands, M. Coventry
Handyside, P. D., M.D., F.R.S.E. Edinburgh.
1867. ‡Hannah, Rev. John, D.C.L. The Vicarage, Brighton.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1853. ‡Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.
*HARCOURT, A. G. VERNON, M.A., F.R.S., F.C.S. 3 Norham-gardens, Oxford.
Harcourt, Egerton V. Vernon, M.A., F.G.S. Whitwell Hall, Yorkshire.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Millbrooke House, Exeter.
1877. §Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1874. ‡Hardman, E. T., F.C.S. 14 Hume street, Dublin.
1872. ‡Hardwicke, Mrs. 192 Piccadilly, London, W.
*HARE, CHARLES JOHN, M.D., Professor of Clinical Medicine in University College, London. 57 Brook-street, Grosvenor-square, London, W.
Harford, Summers. Haverfordwest.
1858. ‡Hargrave, James. Burley, near Leeds.
1876. ‡Harker, Allen. 17 Southgate-street, Gloucester.
1878. *Harkness, H. W. Sacramento, California.
1871. §Harkness, William. Laboratory, Somerset House, London, W.C.
1875. *Harland, Rev. Albert Augustus, M.A., F.S.A. The Vicarage, Harefield, Middlesex.

Year of Election.

1877. *Harland, Henry Seaton. Brompton, Wykeham Station, York.
1862. *HARLEY, GEORGE, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.
*Harley, John. Ross Hall, near Shrewsbury.
1862. *HARLEY, Rev. ROBERT, F.R.S., F.R.A.S. Mill Hill School, Middlesex; and Burton Bank, Mill Hill, Middlesex, N.W.
1861. ‡*Harman, H. W., C.E. 16 Booth-street, Manchester.*
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1872. §Harpley, Rev. William, M.A., F.C.P.S. Clayhanger Rectory, Tiverton.
*Harris, Alfred. Oxton Hall, Tadcaster.
*Harris, Alfred, jun. Lunefield, Kirkby-Lonsdale, Westmoreland.
1871. ‡HARRIS, GEORGE, F.S.A. Iselipps Manor, Northolt, Southall, Middlesex.
1878. *Harris, Herbert W. 124 Lower Baggot-street, Dublin.
1863. ‡Harris, T. W. Grange, Middlesbrough-on-Tees.
1873. ‡Harris, W. W. Oak-villas, Bradford, Yorkshire.
1860. ‡Harrison, Rev. Francis, M.A. Oriel College, Oxford.
1864. ‡Harrison, George. Barnsley, Yorkshire.
1873. §Harrison, George, Ph.D., F.L.S., F.C.S. 14 St. James's-row, Sheffield.
1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *HARRISON, JAMES PARK, M.A. Cintra Park Villa, Upper Norwood, S.E.
1870. ‡HARRISON, REGINALD. 51 Rodney-street, Liverpool.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1863. ‡Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-Tyne.
1853. *Harrison, William, F.S.A., F.G.S. Samlesbury Hall, near Preston, Lancashire.
1849. ‡HARROWBY, The Right Hon. DUDLEY RYDER, Earl of, K.G., D.C.L., F.R.S., F.R.G.S. 39 Grosvenor-square, London, W.; and Sandon Hall, Lichfield.
1859. *Hart, Charles. Harborne Hall, Birmingham.
1876. *Hart, Thomas. Bank View, 33 Preston New-road, Blackburn.
1875. §Hart, W. E. Kilderry, near Londonderry.
1856. ‡*Hartland, F. Dixon, F.S.A., F.R.G.S. The Oaklands, near Cheltenham.*
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel, F.C.S. King's College, London, W.C.
1854. §HARTNUP, JOHN, F.R.A.S. Liverpool Observatory, Bidston, Birkenhead.
1850. ‡Harvey, Alexander. 4 South Wellington-place, Glasgow.
1870. ‡Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
*Harvey, Joseph Charles. Knockrea, Douglas-road, Cork.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1878. §Harvey, R. J., M.D. 7 Upper Merrion-street, Dublin.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-Moors.
1875. ‡Hasting, G. W. Barnard's Green House, Malvern.
Hastings, Rev. H. S. Martley Rectory, Worcester.
1837. ‡Hastings. W. Huddersfield.
1842. *Hatton, James. Richmond House, Higher Broughton, Manchester.
1857. ‡HAUGHTON, Rev. SAMUEL, M.A., M.D., D.C.L., F.R.S., M.R.I.A., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
1874. ‡Hawkins, B. Waterhouse, F.G.S. Century Club, East Fifteenth-street, New York.

Year of Election.

1872. *Hawkshaw, Henry Paul. 20 King-street, St. James's, London, S.W.

*HAWKSHAW, Sir JOHN, C.E., F.R.S., F.G.S., F.R.G.S. Hollycombe, Liphook, Petersfield; and 33 Great George-street, London, S.W.

1864. *Hawkshaw, John Clarke, M.A., F.G.S. 25 Cornwall-gardens, South Kensington, S.W.; and 33 Great George-street, London, S.W.

1868.§§HAWKSLEY, THOMAS, C.E., F.R.S., F.G.S. 30 Great George-street, London, S.W.

1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.

1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.

1877.§§Hay, Arthur J. Lerwick, Shetland.

1861. *HAY, Rear-Admiral the Right Hon. Sir JOHN C. D., Bart, C.B., M.P., D.C.L., F.R.S. 108 St. George's-square, London, S.W.

1858. ‡Hay, Samuel. Albion-place, Leeds.

1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.

1857. ‡Hayden, Thomas, M.D. 30 Harcourt-street, Dublin.

1873. *Hayes, Rev. William A., M.A. 3 Mountjoy-place, Dublin.

1869. ‡Hayward, J. High-street, Exeter.

1858. *HAYWARD, ROBERT BALDWIN, M.A., F.R.S. The Park, Harrow.

1851.§§HEAD, JEREMIAH, C.E., F.C.S. Middlesbrough, Yorkshire.

1869. ‡Head, R. T. The Briars, Alphington, Exeter.

1869. ‡Head, W. R. Bedford-circus, Exeter.

1863. ‡Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.

1872. ‡*Healey, C. E. H. Chadwyck. 8 Albert-mansions, Victoria-street, London, S.W.*

1871. §Healey, George. Matson's, Windermere.

1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.

1877.§§Hearder, Henry Pollington. Westwell-street, Plymouth.

1865. ‡Hearder, William. Rocombe, Torquay.

1877.§§Hearder, William Keep, F.S.A. 195 Union-street, Plymouth.

1866. ‡Heath, Rev. D. J. Esher, Surrey.

1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.

1861. §HEATHFIELD, W. E., F.C.S., F.R.G.S., F.R.S.E. 20 King-street, St. James's, London, S.W.

1865. ‡Heaton, Harry. Harborne House, Harborne, near Birmingham.

1858. *HEATON, JOHN DEAKIN, M.D., F.R.C.P. Claremont, Leeds.

1865. ‡*Heaton, Ralph. Harborne Lodge, near Birmingham.*

1833. ‡HEAVISIDE, Rev. Canon J. W. L., M.A. The Close, Norwich.

1855. ‡HECTOR, JAMES, M.D., F.R.S., F.G.S., F.R.G.S., Geological Survey of New Zealand. Wellington, New Zealand.

1867. ‡HEDDLE, M. FOSTER, M.D., Professor of Chemistry in the University of St. Andrews, N.B.

1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.

1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.

1857. *Hemans, George William, C.E., M.R.I.A., F.G.S. 1 Westminster-chambers, Victoria-street, London, S.W.

1867. ‡Henderson, Alexander. Dundee.

1845. ‡Henderson, Andrew. 120 Gloucester-place, Portman-square, London, W.

1873. *Henderson, A. L. 49 King William-street, London, E.C.

1874. ‡Henderson, James Alexander. Norwood Tower, Belfast.

1876. *Henderson, William. Williamfield, Irvine, N.B.

1873. *HENDERSON, W. D. 12 Victoria-street, Belfast.

1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A., Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland. 3 Idrone-terrace, Blackrock, Co. Dublin.

Year of Election.

1857. ‡Hennessy, John Pope, Governor of the Bahamas. Government House, Nassau.

1873. *Henrici, Olaus M. F. E., Ph.D., F.R.S., Professor of Mathematics in University College, London. 21 South-villas, Camden-square, London, N.W.

Henry, Franklin. Portland-street, Manchester.

Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.

Henry, Mitchell, M.P. Stratheden House, Hyde Park, London, W.

1874. ‡Henry, Rev. P. Shuldam, D.D., M.R.I.A., President, Queen's College, Belfast.

*Henry, William Charles, M.D., F.R.S., F.G.S., F.R.G.S., F.C.S. Haffield, near Ledbury, Herefordshire.

1870. ‡Henty, William. Norfolk-terrace, Brighton.

1855. *Hepburn, J. Gotch, LL.B., F.C.S. Sidcup-place, Sidcup, Kent.

1855. ‡Hepburn, Robert. 9 Portland-place, London, W.

Hepburn, Thomas. Clapham, London, S.W.

1871. ‡Hepburn, Thomas H. St. Mary's Cray, Kent.

Hepworth, John Mason. Ackworth, Yorkshire.

1856. ‡Hepworth, Rev. Robert. 2 St. James's-square, Cheltenham.

*Herbert, Thomas. The Park, Nottingham.

1866. ‡Herrick, Perry. Bean Manor Park, Loughborough.

1871. *Herschel, Professor Alexander S., B.A., F.R.A.S. College of Science, Newcastle-on-Tyne.

1874. §Herschel, Major John, R.E., F.R.S. Mussoorie, N. W. P. India. (Care of Messrs. H. Robertson & Co., 5 Crosby-square, London, E.C.)

1865. ‡Heslop, Dr. Birmingham.

1873. ‡Heugh, John. Gaunt's House, Wimborne, Dorset.

Hey, Rev. William, M.A., F.C.P.S. Clifton, York.

1866. *Heymann, Albert. West Bridgford, Nottinghamshire.

1866. ‡Heymann, L. West Bridgford, Nottinghamshire.

1861. *Heywood, Arthur Henry. Elleray, Windermere.

*Heywood, James, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.

1861. *Heywood, Oliver. Claremont, Manchester.

Heywood, Thomas Percival. Claremont, Manchester.

1875. ‡Hicks, Henry, M.D., F.G.S. Heriot House, Hendon, Middlesex, N.W.

1877. §Hicks, W. M. St. John's College, Cambridge.

1864. *Hiern, W. P., M.A. Castle House, Barnstaple.

1854. *Higgin, Edward. Troston Lodge, near Bury St. Edmunds.

1861. *Higgin, James. Lancaster-avenue, Fennel-street, Manchester.

Higginbotham, Samuel. 4 Springfield-court, Queen-street, Glasgow.

1866. ‡Higginbottom, John, F.R.S., F.R.C.S. Gill-street, Nottingham.

1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.

1871. ‡Higgins, Clement, B.A., F.C.S. 103 Holland-road, Kensington, London, W.

1854. ‡Higgins, Rev. Henry H., M.A. The Asylum, Rainhill, Liverpool.

1861. *Higgins, James. Stocks House, Cheetham, Manchester.

1870. ‡*Higginson, Alfred. 44 Upper Parliament-street, Liverpool.*

Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.

Hill, Arthur. Bruce Castle, Tottenham, Middlesex.

Year of Election.

1872. §Hill, Charles. Rockhurst, West Hoathley, East Grinstead.
*Hill, Rev. Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1857. §Hill, John, C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1871. ‡Hill, Lawrence. The Knowe, Greenock.
*Hill, Sir Rowland, K.C.B., D.C.L., F.R.S., F.R.A.S. Hampstead, London, N.W.
1864. ‡*Hill, William. Combe Hay, Bristol.*
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. *Hills, Thomas Hyde. 338 Oxford-street, London, W.
1858. ‡Hincks, Rev. Thomas, B.A., F.R.S. Stancliff House, Clevedon, Somerset.
1870. ‡Hinde, G. J. Buenos Ayres.
Hindley, Rev. H. J. Edlington, Lincolnshire.
*Hindmarsh, Luke. Alnbank House, Alnwick.
1865. ‡Hinds, James, M.D. Queen's College, Birmingham.
1863. ‡Hinds, William, M.D. Parade, Birmingham.
1861. *Hinmers, William. Cleveland House, Birkdale, Southport.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1861. *Hirst, T. Archer, Ph. D., F.R.S., F.R.A.S. Royal Naval College, Greenwich, S.E.; and Athenæum Club, Pall Mall, London, S.W.
1856. ‡*Hitch, Samuel, M.D. Sandywell Park, Gloucestershire.*
1870. ‡Hitchman, William, M.D., LL.D., F.L.S. 29 Erskine-street, Liverpool.
*Hoare, Rev. George Tooker. Godstone Rectory, Redhill.
Hoare, J. Gurney. Hampstead, London, N.W.
1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.
1866. ‡Hockin, Charles, M.D. 8 Avenue-road, St. John's Wood, London, N.W.
1877. §§Hockin, Edward. Poughill, Stratton, Cornwall.
1877. §Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *Hodgkin, Thomas. Benwell Dene, Newcastle-on-Tyne.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1873. ‡Hodgson, James. Oakfield, Manningham, Bradford, Yorkshire.
1875. *Hodgson, Kirkman Daniel, M.P. 67 Brook-street, London, W.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. North Dene, Gateshead.
1830. ‡Hodgson, W. B., LL.D., F.R.A.S., Professor of Commercial and Political Economy in the University of Edinburgh.
1865. *Hofmann, August Wilhelm, M.D., LL.D., Ph.D., F.R.S., F.C.S. 10 Dorotheen Strasse, Berlin.
1860. ‡Hogan, Rev. A. R., M.A. Watlington Vicarage, Oxfordshire.
1876. ‡*Hogg, Robert. 54 Jane-street, Glasgow.*
1854. *Holcroft, George. Byron's-court, St. Mary's-gate, Manchester.
1873. *Holden, Isaac. Oakworth House, near Keighley, Yorkshire.
1856. ‡Holland, Henry. Dumbleton, Evesham.
*Holland, Philip H. Home Office, London, S.W.
1865. ‡Holliday, William. New-street, Birmingham.
1866. *Holmes, Charles. 59 London-road, Derby.
1873. ‡Holmes, J. R. Southbrook Lodge, Bradford, Yorkshire.

Year of Election.

1876. *Holms, James. Hope Park, Partick, near Glasgow.
1876. ‡Holms, Colonel William, M.P. 95 Cromwell-road, South Kensington, London, S.W.
1870. ‡Holt, William D. 23 Edge-lane, Liverpool.
*Hone, Nathaniel, M.A., M.R.I.A. Bank of Ireland, Dublin.
1875. *Hood, John. The Elms, Cotham Hill, Bristol.
1847. ‡HOOKER, Sir JOSEPH DALTON, K.C.S.I., K.C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S., F.G.S., F.R.G.S. Royal Gardens, Kew, Surrey.
1865. *Hooper, John P. The Hut, Mitcham Common, Surrey.
1877. *Hooper, Samuel F. Beechwood, Clapham Common, Surrey, S.W.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Stanton, Bebington, Cheshire.
1869. ‡*Hope, William, V.C. Parsloes, Barking, Essex.*
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1870. *HOPKINSON, JOHN, F.R.S. 78 Holland-road, Kensington, London, W.
1871. §HOPKINSON, JOHN, F.L.S., F.G.S. Wansford House, Watford.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1876. *Horne, Robert R. 150 Hope-street, Glasgow.
1875. *Horniman, F. J. Surrey House, Forest Hill, London, S.E.
1854. ‡Horsfall, Thomas Berry. Bellamour Park, Rugeley.
1856. ‡Horsley, John H. 1 Ormond-terrace, Cheltenham.
1868. ‡Hotson, W. C. Upper King-street, Norwich.
HOUGHTON, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.R.G.S. 16 Upper Brook-street, London, W.
1858. ‡Hounsfield, James. Hemsworth, Pontefract.
Hovenden, W. F., M.A. Bath.
1859. ‡*Howard, Captain John Henry, R.N. The Deanery, Lichfield.*
1863. ‡Howard, Philip Henry. Corby Castle, Carlisle.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1857. ‡Howell, Henry H., F.G.S. Museum of Practical Geology, Jermyn-street, London, S.W.
1868. ‡HOWELL. Rev. Canon HINDS. Drayton Rectory, near Norwich.
1865. *HOWLETT, Rev. FREDERICK, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡HOWORTH, H. H. Derby House, Eccles, Manchester.
1854. ‡Howson, The Very Rev. J. S., D.D., Dean of Chester. Chester.
1870. ‡Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *HUDSON, HENRY, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1842. §Hudson, Robert, F.R.S., F.G.S., F.L.S. Clapham Common, London, S.W.
1867. ‡Hudson, William H. H., M.A. 19 Bennet's-hill, Doctors' Commons, London, E.C.; and St. John's College, Cambridge.
1858. *HUGGINS, WILLIAM, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse Hill, Brixton, London, S.W.
1857. ‡Huggon, William. 30 Park-row, Leeds.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.
1876. *Hughes, Thomas Edward. The Priory, Repton, Burton-on-Trent.
1868. §HUGHES, T. M'K., M.A., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1863. ‡Hughes, T. W. 4 Hawthorn-terrace, Newcastle-on-Tyne.

Year of
Election.

1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1867. §HULL, EDWARD, M.A., F.R.S., F.G.S., Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1861. ‡HUME, Rev. Canon ABRAHAM, D.C.L., LL.D., F.S.A. All Souls' Vicarage, Rupert-lane, Liverpool.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1878. §Humphreys, H. Castle-square, Carnarvon.
1862. *HUMPHRY, GEORGE MURRAY, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Grove Lodge, Cambridge.
1877. *Hunt, Arthur Roope, M.A., F.G.S. Southwood, Torquay.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1840. ‡HUNT, ROBERT, F.R.S., Keeper of the Mining Records. Museum of Practical Geology, Jermyn-street, London, S.W.
1864. ‡Hunt, W. 72 Pulteney-street, Bath.
1875. *Hunt, William. The Woodlands, Tyndall's Park, Clifton, Bristol.
Hunter, Andrew Galloway. Denholm, Hawick, N.B.
1868. ‡Hunter, Christopher. Alliance Insurance Office, North Shields.
1867. ‡Hunter, David. Blackness, Dundee.
1869. *Hunter, Rev. Robert, F.G.S. 9 Mecklenburgh-street, London, W.C.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1875.§§Hurnard, James. Lexden, Colchester, Essex.
1869. ‡Hurst, George. Bedford.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. Coney-street, York.
1876. ‡Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.
1874. ‡Hutchinson, Thomas J., F.R.G.S. Chimoo Cottage, Mill Hill, London, N.W.
1876. ‡Hutchison, Peter. 28 Berkeley-terrace, Glasgow.
1868. *Hutchison, Robert, F.R.S.E. 29 Chester-street, Edinburgh.
1863. ‡*Hutt, The Right Hon. Sir W., K.C.B. Gibside, Gateshead.*
Hutton, Crompton. Putney Park, Surrey, S.W.
1864. *Hutton, Darnton. (Care of Arthur Lupton, Esq., Headingley, near Leeds.)
Hutton, Henry. Edenfield, Dundrum, Co. Dublin.
1857. ‡Hutton, Henry D. 10 Lower Mountjoy-street, Dublin.
1861. *HUTTON, T. MAXWELL. Summerhill, Dublin.
1852. ‡HUXLEY, THOMAS HENRY, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S., Professor of Natural History in the Royal School of Mines. 4 Marlborough-place, London, N.W.
Hyde, Edward. Dukinfield, near Manchester.
1871. *Hyett, Francis A. Painswick House, Stroud, Gloucestershire.

Ihne, William, Ph.D. Heidelberg.
1873. §Ikin, J. I. 19 Park-place, Leeds.
1861. ‡Iles, Rev. J. H. Rectory, Wolverhampton.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1876. §Inglis, Anthony. Broomhill, Partick, Glasgow.
1871. ‡INGLIS, The Right Hon. JOHN, D.C.L., LL.D., Lord Justice General of Scotland. Edinburgh.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.

Year of Election.

1858. *Ingram, Hugo Francis Meynell. Temple Newsam, Leeds.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Regius Professor of Greek in the University of Dublin. 2 Wellington-road, Dublin.
1870. *Inman, William. Upton Manor, Liverpool.
Ireland, R. S., M.D. 121 Stephen's-green, Dublin.
1857. ‡Irvine, Hans, M.A., M.B. 1 Rutland-square, Dublin.
1862. ‡ISELIN, J. F., M.A., F.G.S. 52 Stockwell Park-road, London, S.W.
1863. *Ivory, Thomas. 23 Walker-street, Edinburgh.

1865. ‡Jabet, George. Wellington-road, Handsworth, Birmingham.
1870. ‡Jack, James. 26 Abercromby-square, Liverpool.
1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1876. ‡Jack, William. 19 Lansdowne-road, Notting Hill, London, W.
1866. ‡Jackson, H. W., F.R.A.S., F.G.S. 15 The Terrace, High-road, Lewisham, S.E.
1869. §Jackson, Moses. The Vale, Ramsgate.
Jackson, Professor Thomas, LL.D. St. Andrew's, Scotland.
1863. *Jackson-Gwilt, Mrs. H. Moonbeam Villa, The Grove, New Wimbledon, London, S.W.
1852. ‡JACOBS, BETHEL. 40 George-street, Hull.
1874. *Jaffe, John. Cambridge Villa, Strandtown, near Belfast.
1865. *Jaffray, John. Park-grove, Edgbaston, Birmingham.
1872. ‡James, Christopher. 8 Laurence Pountney Hill, London, E.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1863. *JAMES, Sir WALTER, Bart., F.G.S. 6 Whitehall-gardens, London, S.W.
1858. ‡James, William C. Woodside, Plymouth.
1876. §§Jamieson, J. L. K. The Mansion House, Govan, Glasgow.
1876. ‡Jamieson, Rev. Dr. R. 156 Randolph-terrace, Glasgow.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1870. ‡Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
JARRETT, Rev. THOMAS, M.A., Professor of Arabic in the University of Cambridge. Trunch, Norfolk.
1870. §Jarrold, John James. London-street, Norwich.
1862. ‡Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, W.
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1868. ‡*Jecks, Charles. 26 Langham-place, Northampton.*
1856. ‡Jeffery, Henry M., M.A. 438 High-street, Cheltenham.
1855. *Jeffray, John. Cardowan House, Millerston, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. 5 Brick-court, Temple, London, E.C.
1861. *JEFFREYS, J. GWYN, LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S. Ware Priory, Herts.
1852. ‡JELLETT, Rev. JOHN H., B.D., M.R.I.A. 64 Lower Leeson-street, Dublin.
1862. §JENKIN, H. C. FLEEMING, F.R.S. M.I.C.E., Professor of Civil Engineering in the University of Edinburgh. 3 Great Stuart-street, Edinburgh.
1873. §Jenkins, Major-General J. J. 14 St. James's-square, London, S.W.
Jennette, Matthew. 106 Conway-street, Birkenhead.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1872. ‡Jennings, W. Grand Hotel, Brighton.

Year of
Election.

1878. §Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.
*Jerram, Rev. S. John, M.A. Chobham Vicarage, near Bagshot, Surrey.
1872. ‡Jesson, Thomas. 7 Upper Wimpole-street, Cavendish-square London, W.
Jessop, William, jun. Butterley Hall, Derbyshire.
1870. *JEVONS, W. STANLEY, M.A., LL.D., F.R.S., Professor of Political Economy in University College, London. 2 The Chestnuts, Branch Hill, Hampstead Heath, London, N.W.
1872. *Joad, George C. Oakfield, Wimbledon, Surrey, S.W.
1871. *Johnson, David, F.C.S., F.G.S. Irvon Villa, Grosvenor-road, Wrexham.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1875. §Johnson, James Henry, F.G.S. 3 Queen's-road, Southport.
1866. ‡Johnson, John. Knighton Fields, Leicester.
1866. ‡Johnson, John G. 18A Basinghall-street, London, E.C.
1872. ‡Johnson, J. T. 27 Dale-street, Manchester.
1861. ‡Johnson, Richard. 27 Dale-street, Manchester.
1870. §Johnson, Richard C., F.R.A.S. Higher Bebington Hall, Birkenhead.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
*Johnson, Thomas. The Hermitage, Frodsham, Cheshire.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham.
1871. ‡Johnston, A. Keith, F.R.G.S. 1 Savile-row, London, W.
1864. ‡Johnston, David. 13 Marlborough-buildings, Bath.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.W.
1876. ‡*Johnston, John, M.D. Edinburgh.*
*Johnstone, James. Alva House, Alva, by Stirling, N.B.
1864. ‡Johnstone, John. 1 Barnard-villas, Bath.
1876. ‡Johnstone, William. 5 Woodside-terrace, Glasgow.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. §Jolly, William (H.M. Inspector of Schools). Inverness, N.B.
1849. ‡Jones, Baynham. Selkirk Villa, Cheltenham.
1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.
1877. §Jones, Henry C., F.C.S. 166 Blackstock-road, London, N.
1865. ‡*Jones, John.* 49 *Union-passage, Birmingham.*
*Jones, Robert. 2 Castle-street, Liverpool.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S., Professor of Geology and Mineralogy, Royal Military and Staff Colleges, Sandhurst. 5 College-terrace, York Town, Surrey.
1847. ‡JONES, THOMAS RYMER, F.R.S. 52 Cornwall-road, Westbourne Park, London, W.
1864.§§JONES, Sir WILLOUGHBY, Bart., F.R.G.S. Cranmer Hall, Fakenham, Norfolk.
1875. *Jose, J. E. 3 Queen-square, Bristol.
*Joule, Benjamin St. John B. 28 Leicester-street, Southport, Lancashire.
1842. *JOULE, JAMES PRESCOTT, LL.D., F.R.S., F.C.S. 12 Wardle-road, Sale, near Manchester.
1847. ‡JOWETT, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.
1858. ‡Jowett, John. Leeds.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, London, S.W.

Year of
Election.

1848. *Joy, Rev. Charles Ashfield. Grove Parsonage, Wantage, Berkshire.
Joy, Rev. John Holmes, M.A. 3 Coloney-terrace, Tunbridge Wells.
*Jubb, Abraham. Halifax.
1870. ‡Judd, John Wesley, F.R.S., F.G.S. 6 Manor-view, Brixton, London, S.W.
1863. ‡*Jukes, Rev. Andrew. Spring Bank, Hull.*

1868. *Kaines, Joseph, M.A., D.Sc. 13 Finsbury-place South, London, E.C.
KANE, Sir ROBERT, M.D., LL.D., F.R.S., M.R.I.A., F.C.S., Principal of the Royal College of Cork. Fortland, Killiney, Co. Dublin.
1857. ‡Kavanagh, James W. Grenville, Rathgar, Ireland.
1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, London, W.
Kay, John Cunliff. Fairfield Hall, near Skipton.
*Kay, John Robinson. Walmersley House, Bury, Lancashire.
Kay, Robert. Haugh Bank, Bolton-le-Moors.
1847. *Kay, Rev. William, D.D. Great Leghs Rectory, Chelmsford.
1872. ‡Keames, William M. 5 Lower Rock-gardens, Brighton.
1875. ‡Keeling, George William. Tuthill, Lydney.
1866. ‡*Keene, Alfred. Eastnoor House, Leamington.*
1850. ‡KELLAND, Rev. PHILIP, M.A., F.R.S. L. & E., Professor of Mathematics in the University of Edinburgh. 20 Clarendon-crescent, Edinburgh.
1878. *Kelland, William Henry. 110 Jermyn-street, London, S.W.; and Grettans, Bow, North Devon.
1876. ‡Kelly, Andrew G. The Manse, Alloa, N.B.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1853. ‡Kemp, Rev. Henry William, B.A. The Charter House, Hull.
1875. ‡KENNEDY, ALEXANDER B. W., C.E., Professor of Engineering in University College, London. 9 Bartholomew-road, London, N.W.
1876. ‡Kennedy, Hugh. Redclyffe, Partickhill, Glasgow.
1857. ‡*Kennedy, Lieut.-Colonel John Pitt. 20 Torrington-square, Bloomsbury, London, W.C.*
1865. ‡Kenrick, William. Norfolk-road, Edgbaston, Birmingham.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1857. ‡Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.
1857. ‡*Kenworth, James Ryley. 7 Pembroke-place, Liverpool.*
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1855. *Ker, Robert. Dougalston, Milngavie, N.B.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1868. ‡Kerrison, Roger. Crown Bank, Norwich.
1869. *Kesselmeyer, Charles A. 1 Peter-street, Manchester.
1869. *Kesselmeyer, William Johannes. 1 Peter-street, Manchester.
1861. *Keymer, John. Parker-street, Manchester.
1876. ‡Kidston, J. B. West Regent-street, Glasgow.
1876. ‡Kidston, William. Ferniegair, Helensburgh, N.B.
1865. *Kinahan, Edward Hudson, M.R.I.A. 11 Merrion-square North, Dublin.
1878. §Kinahan, Edward Hudson, jun. 11 Merrion-square North, Dublin.
1860. ‡KINAHAN, G. HENRY, M.R.I.A., Geological Survey of Ireland. 14 Hume-street, Dublin.
1858. ‡*Kincaid, Henry Ellis, M.A. 8 Lyddon-terrace, Leeds.*
1875. *Kinch, Edward, F.C.S. Agricultural College, Home Department, Tokio, Japan. (Care of C. J. Kinch, Esq., Eaton Hasting, Lechlade, Gloucestershire.)

Year of Election.
1872. *King, Mrs. E. M. 34 Cornwall-road, Westbourne Park, London, W.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Herbert Poole. Theological College, Salisbury.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1870. §King, John Thomson, C.E. 4 Clayton-square, Liverpool.
King, Joseph. Blundell Sands, Liverpool.
1864. §KING, KELBURNE, M.D. 27 George-street, and Royal Institution, Hull.
1860. *King, Mervyn Kersteman. 16 Vyvyan-terrace, Clifton, Bristol.
1875. *King, Percy L. Avonside, Clifton, Bristol.
1870. ‡King, William. 13 Adelaide-terrace, Waterloo, Liverpool.
King, William Poole, F.G.S. Avonside, Clifton, Bristol.
1869. ‡Kingdon, K. Taddiford, Exeter.
1861. ‡Kingsley, John. Ashfield, Victoria Park, Manchester.
1876. §Kingston, Thomas. Strawberry House, Chiswick, Middlesex.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1875. §KINGZETT, CHARLES T., F.C.S. 12 Auriol-road, The Cedars, West Kensington, London, W.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1867. *KINNAIRD, The Right Hon. Lord. 2 Pall Mall East, London, S.W.; and Rossie Priory, Inchture, Perthshire.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1863. ‡Kirkaldy, David. 28 Bartholomew-road North, London, N.W.
1860. ‡KIRKMAN, Rev. THOMAS P., M.A., F.R.S. Croft Rectory, near Warrington.
Kirkpatrick, Rev. W. B., D.D. 48 North Great George-street, Dublin.
1876. *Kirkwood, Anderson, LL.D., F.R.S.E. 12 Windsor-terrace West, Hillhead, Glasgow.
1875. ‡Kirsop, John. 6 Queen's-crescent, Glasgow.
1870. ‡Kitchener, Frank E. Rugby.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1870. §Kneeshaw, Henry. 2 Gambier-terrace, Liverpool.
1836. Knipe, J. A. Botcherby, Carlisle.
1872. *Knott. George, LL.B., F.R.A.S. Cuckfield, Hayward's Heath, Sussex.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1872. ‡Knowles, James. The Hollies, Clapham Common, S.W.
1842. Knowles, John. The Lawn, Rugby.
1874. §Knowles, William James. Cullybackey, Belfast, Ireland.
1876. ‡Knox, David N., M.A., M.B. 8 Belgrave Terrace, Hillhead, Glasgow.
*Knox, George James. 2 Portland-terrace, Regent's Park, London, N.W.
1835. Knox, Thomas B. Union Club, Trafalgar-square, London, W.C.
1875. *Knubley, Rev. E. P. 10 Bridge-road West, Battersea, S.W.
1870. ‡Kynaston, Josiah W. St. Helen's, Lancashire.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

1858. §Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1859. §Ladd, William, F.R.A.S. 11 & 13 Beak-street, Regent-street, London, W.
1870. ‡Laird, H. H. Birkenhead.
Laird, John, M.P. Hamilton-square, Birkenhead.
1870. §Laird, John, jun. Grosvenor-road, Claughton, Birkenhead.
1877. §Lake, W. C., M.D. Teignmouth.

Year of Election.

1859. ‡Lalor, John Joseph, M.R.I.A. 2 Longford-terrace, Monkstown, Co. Dublin.
1846. *Laming, Richard. The Parade, Arundel, Sussex.
1870. ‡*Lamport, Charles. Upper Norwood, Surrey, S.E.*
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1877.§ §Landon, Frederic G. Nelson House, Devonport.
1859. ‡Lang, Rev. John Marshall. Bank House, Morningside, Edinburgh.
1864. §Lang, Robert. Langford Lodge, College-road, Clifton, Bristol.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
*Langton, William. Docklands, Ingatestone, Essex.
1865. ‡Lankester, E. Ray, M.A., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. Exeter College, Oxford.
Lanyon, Sir Charles. The Abbey, White Abbey, Belfast.
1878. §Lapper, E., M.D. 61 Harcourt-street, Dublin.
*Larcom, Major-General Sir Thomas Aiskew, Bart., K.C.B., R.E., F.R.S., M.R.I.A. Heathfield House, Fareham, Hants.
Lassell, William, LL.D., F.R.S.L. & E., F.R.A.S. Ray Lodge, Maidenhead.
1861. *Latham, Arthur G. Lower King-street, Manchester.
1870. *Latham, Baldwin, C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡Laughton, John Knox, M.A., F.R.A.S., F.R.G.S. Royal Naval College, Greenwich, S.E.
1875. ‡Lavington, William F. 107 Pembroke-road, Clifton, Bristol.
1870. *Law, Channell. 5 Champion-park, Camberwell, London, S.E.
1878. §Law, Henry, C.E. 5 Queen Anne's-gate, London, S.W.
1857. ‡Law, Hugh, Q.C. 4 Great Denmark-street, Dublin.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1875. ‡Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.
1869. ‡*Lawson, Henry. 8 Nottingham-place, London, W.*
1857. ‡Lawson, The Right Hon. James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
1876. ‡*Lawson, John. Cluny Hill, Forres, N.B.*
1868. *Lawson, M. Alexander, M.A., F.L.S., Professor of Botany in the University of Oxford. Botanic Gardens, Oxford.
1863. ‡Lawton, Benjamin C. Neville Chambers, 44 Westgate-street, Newcastle-upon-Tyne.
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
1865. ‡Lea, Henry. 35 Paradise-street, Birmingham.
1857. ‡Leach, Captain R. E. Mountjoy, Phœnix Park, Dublin.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Old Change, London, E.C.; and Painshill, Cobham.
1847. *Leatham, Edward Aldam, M.P. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
1844. *Leather, John Towlerton, F.S.A. Leventhorpe Hall, near Leeds.
1858. ‡Leather, John W. Newton-green, Leeds.
1863. ‡Leavers, J. W. The Park, Nottingham.
1872. ‡Lebour, G. A., F.G.S. Weedpark House, Dipton, Lintz Green, Co. Durham.
1858. *Le Cappelain, John. Wood-lane, Highgate, London, N.
1858. ‡Ledgard, William. Potter Newton, near Leeds.
1861. ‡Lee, Henry. Irwell House, Lower Broughton, Manchester.

Year of Election.

1853. *LEE, JOHN EDWARD, F.G.S., F.S.A. Villa Syracusa, Torquay.
1859. ‡Lees, William. Link Vale Lodge, Viewforth, Edinburgh.
*Leese, Joseph. Glenfield, Altrincham, Manchester.
*Leeson, Henry B., M.A., M.D., F.R.S., F.C.S. The Maples, Bonchurch, Isle of Wight.
1872. ‡LEFEVRE, G. SHAW, M.P., F.R.G.S. 18 Spring-gardens, London, S.W.
*LEFROY, Lieut.-General Sir JOHN HENRY, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S. 82 Queen's-gate, London, S.W.
*Legh, Lieut.-Colonel George Cornwall, M.P. High Legh Hall, Cheshire; and 43 Curzon-street, Mayfair, London, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1868. ‡LEICESTER, The Right Hon. the Earl of. Holkham, Norfolk.
1856. ‡LEIGH, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1870. ‡Leighton, Andrew. 35 High-park-street, Liverpool.
1867. §Leishman, James. Gateacre Hall, Liverpool.
1870. ‡Leister, G. F. Gresbourn House, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1863. *LENDY, Captain AUGUSTE FREDERIC, F.L.S., F.G.S. Sunbury House, Sunbury, Middlesex.
1867. ‡Leng, John. 'Advertiser' Office, Dundee.
1878. §Lennon, Rev. Francis. The College, Maynooth, Ireland.
1861. ‡Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London, S.W.
Lentaigne, John, C.B., M.D. Tallaght House, Co. Dublin; and 1 Great Denmark-street, Dublin.
Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1871. §LEONARD, HUGH, F.G.S., M.R.I.A., F.R.G.S.I. Geological Survey of Ireland, 14 Hume-street, Dublin.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1861. ‡Leppoc, Henry Julius. Kersal Crag, near Manchester.
1872. ‡Lermit, Rev. Dr. School House, Dedham.
1871. ‡Leslie, Alexander, C.E. 72 George-street, Edinburgh.
1856. ‡Leslie, Colonel J. Forbes. Rothienorman, Aberdeenshire.
1852. ‡LESLIE, T. E. CLIFFE, LL.B., Professor of Jurisprudence and Political Economy, Queen's College, Belfast.
1876. ‡*Leveson, Edward John. Cluny, Sydenham Hill, S.E.*
1866. §LEVI, Dr. LEONE, F.S.A., F.S.S., F.R.G.S., Professor of Commercial Law in King's College, London. 5 Crown Office-row, Temple, London, E.C.
1870. ‡LEWIS, ALFRED LIONEL. 151 Church-road, De Beauvoir Town, London, N.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡LIDDELL, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, The Right Rev. CHARLES GRAVES, D.D., M.R.I.A., Lord Bishop of. The Palace, Henry-street, Limerick.
1878. §Lincolne, William. Ely, Cambridgeshire.
*Lindsay, Charles. Ridge Park, Lanark, N.B.
1871. *LINDSAY, The Right Hon. Lord, M.P., F.R.S. 47 Brook-street, London, W.
1871. ‡*Lindsay, Rev. T. M. 7 Great Stuart-street, Edinburgh.*
1870. ‡Lindsay, Thomas, F.C.S. 288 Renfrew-street, Glasgow.
1842. *Lingard, John R., F.G.S. 4 Westminster-chambers, London, S.W.

Year of Election.

Lingwood, Robert M., M.A., F.L.S., F.G.S. 1 Derby-villas, Cheltenham.
1876. §Linn, James. Geological Survey Office, India-buildings, Edinburgh.
Lister, James. Liverpool Union Bank, Liverpool.
1873. **Lister*, *Samuel Cunliffe*. *Farfield Hall, Addingham, Leeds.*
1870. §Lister, Thomas. Victoria-crescent, Barnsley, Yorkshire.
1876. ‡Little, Thomas Evelyn. 42 Brunswick-street, Dublin.
Littledale, Harold. Liscard Hall, Cheshire.
1861. *LIVEING, G. D., M.A., F.C.S., Professor of Chemistry in the University of Cambridge. Cambridge.
1876. *Liversidge, Archibald, F.C.S., F.G.S., F.R.G.S., Professor of Geology and Mineralogy in the University of Sydney, N.S.W. (Care of Messrs. Trubner & Co., Ludgate Hill, London, E.C.)
1864. §Livesay, J. G. Cromarty House, Ventnor, Isle of Wight.
1860. ‡*Livingstone, Rev. Thomas Gott, Minor Canon of Carlisle Cathedral.*
Lloyd, Rev. A. R. Hengold, near Oswestry.
Lloyd, Rev. C., M.A. Whittington, Oswestry.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B. Edgbaston-grove, Birmingham.
*Lloyd, George, M.D., F.G.S. Park Glass Works, Birmingham.
*LLOYD, Rev. HUMPHREY, D.D., LL.D., F.R.S. L. & E., M.R.I.A., Provost of Trinity College, Dublin.
1870. ‡*Lloyd, James.* 16 *Welfield-place, Liverpool.*
1870. ‡*Lloyd, J. H., M.D. Anglesey, North Wales.*
1865. ‡Lloyd, John. Queen's College, Birmingham.
Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
1877. *Lloyd, Sampson Samuel, M.P. Moor Hall, Sutton Coldfield.
1865. *Lloyd, Wilson, F.R.G.S. Myrod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S., F.R.G.S. 59 Clarendon-road, Kensington Park, London, W.
1853. *Locke, John. 133 Leinster-road, Dublin.
1867. *Locke, John. 83 Addison-road, Kensington, London, W.
1872. ‡LOCKE, JOHN, M.P. 63 Eaton-place, London, S.W.
1863. ‡LOCKYER, J. NORMAN, F.R.S., F.R.A.S. 16 Penywern-road, South Kensington, London, S.W.
1875. *LODGE, OLIVER J., D.Sc. University College, London, W.C.; and 17 Parkhurst-road, London, N.
1868. ‡Login, Thomas, C.E., F.R.S.E. India.
1862. ‡Long, Andrew, M.A. King's College, Cambridge.
1876. ‡Long, H. A. Charlotte-street, Glasgow.
1872. ‡Long, Jeremiah. 50 Marine Parade, Brighton.
1871. *Long, John Jex. 727 Duke-street, Glasgow.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1866. §Longdon, Frederick. Osmaston-road, Derby.
LONGFIELD, The Right Hon. MOUNTIFORT, LL.D., M.R.I.A., Regius Professor of Feudal and English Law in the University of Dublin. 47 Fitzwilliam-square, Dublin.
1859. ‡Longmuir, Rev. John, M.A., LL.D. 14 Silver-street, Aberdeen.
1875. *Longstaff, George Blundell, M.A., M.B., F.C.S. Southfield Grange, Wandsworth, S.W.
1871. §Longstaff, George Dixon, M.D., F.C.S. Southfields, Wandsworth, S.W.; and 9 Upper Thames-street, London, E.C.
1872. *Longstaff, Lieut.-Colonel Llewellyn Wood, F.R.G.S. Reform Club, Pall Mall, London, S.W.
1875. §Lonsdale, N. Lowenthal. 1 Southernhay, Clifton, Bristol.
1861. *Lord, Edward. Adamroyd, Todmorden.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.

Year of Election.

1876. *Love, James, F.R.A.S. Talbot Lodge, Bickerton-road, Upper Holloway, London, N.
1875. *Lovett, W. J. 96 Lionel-street, Birmingham.
1867. *Low, James F. Monifieth, by Dundee.
1863. *Lowe, Lieut.-Colonel Arthur S. H., F.R.A.S. 76 Lancaster-gate, London, W.
1861. *Lowe, Edward Joseph, F.R.S., F.R.A.S., F.L.S., F.G.S., F.M.S. Highfield House Observatory, near Nottingham.
1870. ‡Lowe, G. C. 67 Cecil-street, Greenheys, Manchester.
1868. ‡Lowe, John, M.D. King's Lynn.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1853. *Lubbock, Sir John, Bart., M.P., F.R.S., F.L.S., F.G.S. High Elms, Farnborough, Kent.
1870. ‡Lubbock, Montague. High Elms, Farnborough, Kent.
1878. §Lucas, Joseph. Tooting Graveney, London, S.W.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1875. §Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1867. *Luis, John Henry. Cidhmore, Dundee.
1873. ‡Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.
1866. *Lund, Charles. 48 Market-street, Bradford, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. Tweed Lodge, Charles-street, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1858. *Lupton, Arthur. Headingley, near Leeds.
1864. *Lupton, Darnton. The Harehills, near Leeds.
1874. *Lupton, Sydney. Harrow.
1864. *Lutley, John. Brockhampton Park, Worcester.
1866 ‡Lycett, Sir Francis. 18 Highbury-grove, London, N.
1871. ‡Lyell, Leonard. 42 Regent's Park-road, London, N.W.
1874. ‡Lynam, James, C.E. Ballinasloe, Ireland.
1857. ‡Lyons, Robert D., M.B., M.R.I.A. 8 Merrion-square West, Dublin.
1878. §Lyte, Cecil Maxwell. Scientific Club, Savile-row, London, W.
1862. *Lyte, F. Maxwell, F.C.S. 6 Cité de Retiro, Faubourg St. Honoré, Paris.

1852. ‡McAdam, Robert. 18 College-square East, Belfast.
1854. *Macadam, Stevenson, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1876. ‡M'Adam, William. 30 St. Vincent-crescent, Glasgow.
1876. *Macadam, William Ivison. Surgeons' Hall, Edinburgh.
1868. ‡Macalister, Alexander, M.D., Professor of Zoology in the University of Dublin. 13 Adelaide-road, Dublin.
1878. §McAlister, Donald, B.A., B.Sc. St. John's College, Cambridge.
1868. ‡M'Allan, W. A. Norwich.
1866. *M'Arthur, A., M.P. Raleigh Hall, Brixton Rise, London, S.W.
1840. Macaulay, James A. M., M.D. 22 Cambridge-road, Kilburn, London, N.W.
1871. ‡M'Bain, James, M.D., R.N. Logie Villa, York-road, Trinity, Edinburgh.
*MacBrayne, Robert. Messrs. Black and Wingate, 5 Exchange-square, Glasgow.
1866. ‡M'Callan, Rev. J. F., M.A. Basford, near Nottingham.
1863. ‡M'Calmont, Robert. Gatton Park, Reigate.
1855. ‡M'Cann, Rev. James, D.D., F.G.S. 18 Shaftesbury-terrace, Glasgow.
1876. *M'Clelland, A. S. 4 Crown-gardens, Dowanhill, Glasgow.

Year of
Election.

1840. M'Clelland, James, F.S.S. 32 Pembridge-square, London, W.
1868. ‡M'Clintock, Rear-Admiral Sir Francis L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. *M'Clure, J. H. The Telephone Company, 115 Cannon-street, London, E.C.
1874. ‡M'Clure, Sir Thomas, Bart. Belmont, Belfast.
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
*M'Connel, James. Moore-place, Esher, Surrey.
1859. *M'Connell, David C., F.G.S. 44 Manor-place, Edinburgh.
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
1876. ‡M'Culloch, Richard. 109 Douglas-street, Blythswood-square, Glasgow.
1871. ‡M'Donald, William. Yokohama, Japan. (Care of R. K. Knevitt, Esq., Sun-court, Cornhill, E.C.)
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1878. §McDonnell, Robert, M.D., F.R.S., M.R.I.A. 14 Lower Pembroke-street, Dublin.
*M'Ewan, John. 9 Melville-terrace, Stirling, N.B.
1859. ‡Macfarlane, Alexander. 73 Bon Accord-street, Aberdeen.
1871. §§M'Farlane, Donald. The College Laboratory, Glasgow.
1855. *Macfarlane, Walter. 22 Park-circus, Glasgow.
1854. **Macfie, Robert Andrew.* 13 *Victoria-street, Westminster, S.W.*
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1872. ‡M'George, Mungo. Nithsdale, Laurie Park, Sydenham, S.E.
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1855. ‡M'Gregor, Alexander Bennett. 19 Woodside-crescent, Glasgow.
1855. ‡MacGregor, James Watt. 2 Laurence-place, Partick, Glasgow.
1876. ‡M'Grigor, Alexander B. 19 Woodside-terrace, Glasgow.
1859. ‡M'Hardy, David. 54 Netherkirkgate, Aberdeen.
1874. §MacIlwaine, Rev. William, D.D., M.R.I.A. Ulsterville, Belfast.
1876. §§Macindoe, Patrick. 9 Somerset-place, Glasgow.
1859. ‡Macintosh, John. Middlefield House, Woodside, Aberdeen.
1867. *M'Intosh, W. C., M.D., F.R.S. L. & E., F.L.S. Murthly, Perthshire.
1854. *MacIver, Charles. 8 Abercromby-square, Liverpool.
1871. ‡Mackay, Rev. A., LL.D., F.R.G.S. 2 Hatton-place, Grange, Edinburgh.
1873. ‡McKendrick, John G., M.D., F.R.S.E. 2 Chester-street, Edinburgh.
1865. ‡Mackeson, Henry B., F.G.S. Hythe, Kent.
1872. *Mackey, J. A. 24 Buckingham-place, Brighton.
1867. §Mackie, Samuel Joseph, F.G.S. 84 Kensington Park-road, London, W.
*Mackinlay, David. Great Western-terrace, Hillhead, Glasgow.
1865. ‡Mackintosh, Daniel, F.G.S. 36 Derby-road, Higher Tranmere, Birkenhead.
1850. ‡Macknight, Alexander. 12 London-street, Edinburgh.
1867. ‡Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *McLachlan, Robert, F.R.S., F.L.S. 39 Limes-grove, Lewisham, S.E.
1873. ‡McLandsborough, John, C.E., F.R.A.S., F.G.S. Shipley, near Bradford, Yorkshire.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. §§MacLaren, Duncan, M.P. Newington House, Edinburgh.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1876. ‡M'Lean, Charles. 6 Claremont-terrace, Glasgow.
1876. ‡M'Lean, Mrs. Charles. 6 Claremont-terrace, Glasgow.

Year of Election.

1859. ‡MACLEAR, Sir THOMAS, F.R.S., F.R.G.S., F.R.A.S. Cape Town, South Africa.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Campden-hill-road, London, W.
1868. §§M'LEOD, HERBERT, F.C.S. Indian Civil Engineering College, Cooper's Hill, Egham.
1875. ‡Macliver, D. 1 Broad-street, Bristol.
1875. ‡Macliver, P. S. 1 Broad-street, Bristol.
1861. *Maclure, John William. 2 Bond-street, Manchester.
1878. *M'Master, George, M.A., J.P. Donnybrook, Ireland.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey, S.W.
1874. §§MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1871. ‡M'NAB, WILLIAM RAMSAY, M.D., Professor of Botany in the Royal College of Science, Dublin. 4 Vernon-parade, Clontarf, Dublin.
1870. ‡Macnaught, John, M.D. 74 Huskisson-street, Liverpool.
1867. §M'Neill, John. Balhousie House, Perth.
MACNEILL, The Right Hon. Sir JOHN, G.C.B., F.R.S.E., F.R.G.S. Granton House, Edinburgh.
MACNEILL, Sir JOHN, LL.D., F.R.S., F.R.A.S., M.R.I.A. 17 The Grove, South Kensington, London, S.W.
1878. §Macnie, George. 59 Bolton-street, Dublin.
1852. *Macrory, Adam John. Duncairn, Belfast.
*MACRORY, EDMUND, M.A. 40 Leinster-square, Bayswater, London, W.
1876. *Mactear, James. 16 Burnbank-gardens, Glasgow.
1855. ‡M'Tyre, William, M.D. Maybole, Ayrshire.
1855. ‡MACVICAR, Rev. JOHN GIBSON, D.D., LL.D. Moffat, N.B.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Philip. 48 Gloucester-place, Portman-square, London, W.
1878. §Mahony, W. A. 34 College-green, Dublin.
1869. ‡Main, Robert. Admiralty, Whitehall, London, S.W.
1866. §§MAJOR, RICHARD HENRY, F.S.A., Sec.R.G.S. British Museum, London, W.C.
*MALAHIDE, The Right Hon. Lord TALBOT DE, M.A., D.C.L., F.R.S., F.G.S., F.S.A., M.R.I.A. Malahide Castle, Co. Dublin.
*Malcolm, Frederick. Morden College, Blackheath, London, S.E.
1870. *Malcolm, Sir James, Bart. 1 Cornwall-gardens, South Kensington, London, S.W.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1863. ‡Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, U.S.
*MALLET, ROBERT, Ph.D., F.R.S., F.G.S., M.R.I.A. Enmore, The Grove, Clapham-road, Clapham, S.W.
1876. ‡Malloch, C. 7 Blythwood-square, Glasgow.
1846. ‡MANBY, CHARLES, F.R.S., F.G.S. 60 Westbourne-terrace, Hyde Park, London, W.
1870. ‡Manifold, W. H. 45 Rodney-street, Liverpool.
1866. §MANN, ROBERT JAMES, M.D., F.R.A.S. 5 Kingsdown-villas, Wandsworth Common, S.W.
Manning, His Eminence Cardinal. Archbishop's House, Westminster, S.W.
1866. ‡Manning, John. Waverley-street, Nottingham.
1878. §Manning, Robert. 4 Upper Ely-place, Dublin.
1864. ‡Mansel, J. C. Long Thorns, Blandford.
1870. ‡Marcoartu, Senor Don Arturo de. Madrid.
1864. ‡MARKHAM, CLEMENTS R., C.B., F.R.S., F.L.S., Sec.R.G.S., F.S.A. 21 Eccleston-square, Pimlico, London, S.W.

Year of Election.

1863. ‡Marley, John. Mining Office, Darlington.
*Marling, Samuel S., M.P. Stanley Park, Stroud, Gloucestershire.
1871. §§MARRECO, A. FREIRE-. College of Physical Science, Newcastle-on-Tyne.
1857. ‡Marriott, William, F.C.S. Grafton-street, Huddersfield.
1842. Marsden, Richard. Norfolk-street, Manchester.
1870. ‡Marsh, John. Rann Lea, Rainhill, Liverpool.
1865. ‡Marsh, J. F. Hardwick House, Chepstow.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1852. ‡Marshall, James D. Holywood, Belfast.
1876. ‡Marshall, Peter. 6 Parkgrove-terrace, Glasgow.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1849. *Marshall, William P. 6 Portland-road, Edgbaston, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1878. §Martin, H. Newell. Christ's College, Cambridge.
1871. ‡Martin, Rev. Hugh, M.A. Greenhill Cottage, Lasswade, by Edinburgh.
1870. ‡*Martin, Robert, M.D.* 120 *Upper Brook-street, Manchester.*
1836. Martin, Studley. 177 Bedford-street South, Liverpool.
1867. ‡Martin, William Young. 3 Airlie-place, Dundee.
*Martindale, Nicholas. Meadow Bank, Vanbrugh-fields, Blackheath, S.E.
*Martineau, Rev. James, LL.D., D.D. 5 Gordon-street, Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1875. ‡Martyn, Samuel, M.D. 8 Buckingham-villas, Clifton, Bristol.
1878. §Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, London, E.C.
1847. ‡MASKELYNE, NEVIL STORY, M.A., F.R.S., F.G.S., Keeper of the Mineralogical Department, British Museum, and Professor of Mineralogy in the University of Oxford. 112 Gloucester-terrace, Hyde Park-gardens, London, W.
1861. *Mason, Hugh. Groby Lodge, Ashton-under-Lyne.
1868. ‡Mason, James Wood, F.G.S. The Indian Museum, Calcutta. (Care of Messrs. Henry S. King & Co., 65 Cornhill, London, E.C.)
1876. §Mason, Robert. 6 Albion-crescent, Dowanhill, Glasgow.
1876. ‡Mason, Stephen. 9 Rosslyn-terrace, Hillhead, Glasgow.
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1870. ‡*Massey, Thomas.* 5 *Gray's-Inn-square, London, W.C.*
1870. ‡Massy, Frederick. 50 Grove-street, Liverpool.
1876. §§Matheson, John. Eastfield, Rutherglen, Glasgow.
1865. *Matthews, G. S. Portland-road, Edgbaston, Birmingham.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 49 Harborne-road, Birmingham.
1876. *Mathiesen, John, jun. Cordale, Renton, Glasgow.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1860. §§Matthews, Rev. Richard Brown. Shalford Vicarage, near Guildford.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Shropshire.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.

Year of Election.

1864. *Maxwell, Francis. St. Germains, Longniddry, East Lothian.
*MAXWELL, JAMES CLERK, M.A., LL.D., F.R.S.L. & E., Professor of Experimental Physics in the University of Cambridge. Glenlair, Dalbeattie, N.B.; and 11 Scroope-terrace, Cambridge.
*Maxwell, Robert Perceval. Groomsport House, Belfast.
1868. ‡Mayall, J. E., F.C.S. Stork's Nest, Lancing, Sussex.
1835. Mayne, Edward Ellis. Rocklands, Stillorgan, Ireland.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1863. ‡Mease, George D. Bylton Villa, South Shields.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1867. ‡MELDRUM, CHARLES, M.A., F.R.S., F.R.A.S. Port Louis, Mauritius.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1877. *Menabrea, Lieut.-General Count. 35 Queen's-gate, London, S.W.
1862.§§MENNELL, HENRY J. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1868. §MERRIFIELD, CHARLES W., F.R.S. 20 Girdler's-road, Brook Green, London, W.
1877.§§Merrifield, John, Ph.D., F.R.A.S. Gascoigne-place, Plymouth.
1871. ‡Merson, John. Northumberland County Asylum, Morpeth.
1872. *Messent, John. 429 Strand, London, W.C.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. ‡MIALL, LOUIS C., F.G.S., Professor of Biology in Yorkshire College, Leeds.
1865. ‡*Michie, Alexander. 26 Austin Friars, London, E.C.*
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1876. *Middleton, Robert T. 197 West George-street, Glasgow.
1866. ‡Midgley, John. Colne, Lancashire.
1867. ‡Midgley, Robert. Colne, Lancashire.
1859. ‡Millar, John, J.P. Lisburn, Ireland.
1863. ‡Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road, London, E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1876. ‡Millar, William. Highfield House, Dennistoun, Glasgow.
1876. §Millar, W. J. 145 Hill-street, Garnethill, Glasgow.
1876. ‡Miller, Daniel. 258 St. George's-road, Glasgow.
1875. ‡Miller, George. Brentry, near Bristol.
1865. ‡Miller, Rev. Canon J. C., D.D. The Vicarage, Greenwich, S.E.
1861. *Miller, Robert. Poise House, Bosden, near Stockport.
1876. *Miller, Robert. 1 Lily Bank-terrace, Hillhead, Glasgow.
1876. ‡Miller, Thomas Paterson. Morriston House, Cambuslang, N.B.
MILLER, WILLIAM HALLOWS, M.A., LL.D., F.R.S., F.G.S., Professor of Mineralogy in the University of Cambridge. 7 Scroope-terrace, Cambridge.
1868. *Milligan, Joseph, F.L.S., F.G.S., F.R.A.S., F.R.G.S. 6 Craven-street, Strand, London, W.C.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in Anderson's University, Glasgow. 234 East George-street, Glasgow.
*Mills, John Robert. 11 Bootham, York.
Milne, Admiral Sir Alexander, Bart., G.C.B., F.R.S.E. 13 New-street, Spring-gardens, London, S.W.

Year of
Election.

1867. ‡Milne, James. Murie House, Errol, by Dundee.
1867. *MILNE-HOME, DAVID, M.A., F.R.S.E., F.G.S. 10 York-place, Edinburgh.
1864. *MILTON, The Right Hon. Lord, F.R.G.S. 17 Grosvenor-street, London, W.; and Wentworth, Yorkshire.
1865. ‡Minton, Samuel, F.G.S. Oakham House, near Dudley.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.
1863. ‡Mitchell, C. Walker. Newcastle-on-Tyne.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1870.§§Mitchell, John. York House, Clitheroe, Lancashire.
1868.§§Mitchell, John, jun. Pole Park House, Dundee.
1855. *Moffat, John, C.E. Ardrossan, Scotland.
1854. §MOFFAT, THOMAS, M.D., F.G.S., F.R.A.S., F.M.S. Hawarden, Chester.
1864. ‡Mogg, John Rees. High Littleton House, near Bristol.
1866.§§MOGGRIDGE, MATTHEW, F.G.S. 8 Bina-gardens, South Kensington, London, S.W.
1855. ‡Moir, James. 174 Gallogate, Glasgow.
1861. ‡Molesworth, Rev. W. N., M.A. Spotland, Rochdale.
Mollan, John, M.D. 8 Fitzwilliam-square North, Dublin.
1878. §Molloy, Constantine. 70 Lower Gardiner-street, Dublin.
1877. *Molloy, Rev. G. 86 Stephen's-green, Dublin.
1852. ‡Molony, William, LL.D. Carrickfergus.
1865. §MOLYNEUX, WILLIAM, F.G.S. Branston Cottage, Burton-upon-Trent.
1860. ‡Monk, Rev. William, M.A., F.R.A.S. Wymington Rectory, Higham Ferrers, Northamptonshire.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1872. §Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, London, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1859. ‡MOORE, CHARLES, F.G.S. 6 Cambridge-terrace, Bath.
1874. §Moore, David, Ph.D., F.L.S., M.R.I.A. Glasnevin, Dublin.
1857. ‡Moore, Rev. John, D.D. Clontarf, Dublin.
Moore, John. 2 Meridian-place, Clifton, Bristol.
*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1866. *MOORE, THOMAS, F.L.S. Botanic Gardens, Chelsea, London, S.W.
1854. ‡MOORE, THOMAS JOHN, Cor. M.Z.S. Free Public Museum, Liverpool.
1877. §Moore, W. F. The Friary, Plymouth.
1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.
1877.§§Moore, William Vanderkemp. 15 Princess-square, Plymouth.
1871. ‡MORE, ALEXANDER G., F.L.S., M.R.I.A. 3 Botanic View, Glasnevin, Dublin.
1873. ‡Morgan, Edward Delmar. 15 Rowland-gardens, London, W.
1868. ‡*Morgan, Thomas H. Oakhurst, Hastings.*
1833. Morgan, William, D.C.L. Oxon. Uckfield, Sussex.
1878. §Morgan, William, Ph.D. Swansea.
1867. ‡Morison, William R. Dundee.
1863. ‡MORLEY, SAMUEL, M.P. 18 Wood-street, Cheapside, London, E.C.
1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.

Year of Election.

*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1876. §§Morris, Rev. S. S. O. The Grammar School, Dolgelly.
1874. ‡Morrison, G. J., C.E. 5 Victoria-street, Westminster, S.W.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1865. §Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §MORTON, GEORGE H., F.G.S. 122 London-road, Liverpool.
1858. *MORTON, HENRY JOSEPH. 4 Royal Crescent, Scarborough.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1857. ‡Moses, Marcus. 4 Westmoreland-street, Dublin.
Mosley, Sir Oswald, Bart., D.C.L. Rolleston Hall, Burton-upon-Trent, Staffordshire.
1878. §Moss, Edward Lawton, M.D., R.N. 48 Haddington-road, Dublin.
Moss, John. Ottersgool, near Liverpool.
1878. *Moss, JOHN FRANCIS. Ranmoor, Sheffield.
1870. ‡Moss, John Miles, M.A. 2 Esplanade, Waterloo, Liverpool.
1876. §Moss, RICHARD JACKSON, F.C.S., M.R.I.A. 66 Kenilworth-square, Rathgar, Dublin.
1873. *Mosse, George Staley. Cowley Hall, near Uxbridge.
1864. *Mosse, J. R. Public Works' Department, Ceylon. (Care of Messrs. H. S. King & Co., 65 Cornhill, London. E.C.)
1873. ‡Mossman, William. Woodhall, Calverley, Leeds.
1869. §MOTT, ALBERT J., F.G.S. Adsett Court, Westbury-on-Severn.
1865. §§Mott, Charles Grey. The Park, Birkenhead.
1866. §Mott, Frederick T., F.R.G.S. Birstall Hill, Leicester.
1872. ‡Mott, Miss Minnie. 1 De Montfort-street, Leicester.
1862. *MOUAT, FREDERICK JOHN, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Fulmodeston Rectory, Dereham, Norfolk.
1878. *Moulton, J. F. 74 Onslow-gardens, London, S.W.
1863. ‡Mounsey, Edward. Sunderland.
Mounsey, John. Sunderland.
1861. *Mountcastle, William Robert. Bridge Farm, Ellenbrook, near Manchester.
1877. §§MOUNT-EDGCUMBE, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.
1874. §Muir, M. M. Pattison, F.R.S.E. Owens College, Manchester.
1876. *Muir, John. 6 Park-gardens, Glasgow.
1876. §§Muir, Thomas. High School, Glasgow.
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. 159 Camden-road, London, N.
1871. *MUIRHEAD, HENRY, M.D. Bushy Hill, Cambuslang, Lanarkshire.
1876. ‡Muirhead, R. F. Meikle Cloak, Lochwinnoch, Renfrewshire.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡MUNDELLA, A. J., M.P., F.R.G.S. The Park, Nottingham.
1876. §Munro, Donald, F.C.S. 97 Eglinton-street, Glasgow.
1860. *MUNRO, Major-General WILLIAM, C.B., F.L.S. United Service Club, Pall Mall, London, S.W.; and Mapperton Lodge, Farnborough, Hants.
1872. *Munster, H. Sillwood Lodge, Brighton.
1871. *Munster, William Felix. 41 Brompton-square, London, W.
1864. §§MURCH, JEROM. Cranwells, Bath.
*Murchison, John Henry. Surbiton Hill, Kingston.
1864. *Murchison, K. R. Brokehurst, East Grinstead.

Year of Election.

1876. ‡Murdoch, James. Altony Albany, Girvan, N.B.
1855. §Murdock, James B. Hamilton-place, Langside, Glasgow.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1869. ‡Murray, Adam. 4 Westbourne-crescent, Hyde Park, London, W.
1871. ‡*Murray, Dr. Ivor, F.R.S.E. The Knowle, Brenchley, Staplehurst, Kent.*
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1871. §Murray, John. 3 Clarendon-crescent, Edinburgh.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, C.E. Downlands, Sutton, Surrey.
‡Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.
1872. ‡Murray, J. Jardine. 99 Montpellier-road, Brighton.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
1859. *Murton, James. Highfield, Silverdale, Carnforth, Lancaster.
Musgrave, The Venerable Charles, D.D., Archdeacon of Craven, Halifax.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1865. ‡*Myers, Rev. E., F.G.S. 3 Waterloo-road, Wolverhampton.*
1859.§§Mylne, Robert William, F.R.S., F.G.S., F.S.A. 21 Whitehall-place, London, S.W.

1842. Nadin, Joseph. Manchester.
1855. *Napier, James R., F.R.S. 22 Blythwood-square, Glasgow.
1876.§§Napier, James S. 9 Woodside-place, Glasgow.
1876. ‡Napier, John. Saughfield House, Hillhead, Glasgow.
*Napier, Captain Johnstone, C.E. Laverstock House, Salisbury.
1839. *Napier, The Right Hon. Sir Joseph, Bart., D.C.L., LL.D. 4 Merrion-square South, Dublin.
Napper, James William L. Loughcrew, Oldcastle, Co. Meath.
1872. §Nares, Captain Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 23 St. Philip's-road, Surbiton.
1866. ‡Nash, Davyd W., F.S.A., F.L.S. 10 Imperial-square, Cheltenham.
1850. *Nasmyth, James. Penshurst, Tunbridge.
1864. ‡Natal, Rev. John William Colenso, D.D., Lord Bishop of. Natal.
1860. ‡Neate, Charles, M.A. Oriel College, Oxford.
1873. ‡Neill, Alexander Renton. Fieldhead House, Bradford, Yorkshire.
1873. ‡Neill, Archibald. Fieldhead House, Bradford, Yorkshire.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1865. ‡Neilson, W. Montgomerie. Glasgow.
1876.§§Nelson, D. M. 48 Gordon-street, Glasgow.
Ness, John. Helmsley, near York.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1866. *Nevill, Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1857. ‡Neville, John, C.E., M.R.I.A. Roden-place, Dundalk, Ireland.
1852. ‡Neville, Parke, C.E., M.R.I.A. 58 Pembroke-road, Dublin.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
Newall, Henry. Hare Hill, Littleborough, Lancashire.
*Newall, Robert Stirling, F.R.S., F.R.A.S. Ferndene, Gateshead-upon-Tyne.
1866. *Newdegate, Albert L. 2 The Pavement, Clapham Common, London, S.W.
1876. §Newhaus, Albert. 1 Prince's-terrace, Glasgow.

Year of
Election.

1842. *NEWMAN, Professor FRANCIS WILLIAM. 15 Arundel-crescent, Weston-super-Mare.

1863. *NEWMARCH, WILLIAM, F.R.S. Beech Holme, Balham, London, S.W.

1866. *Newmarch, William Thomas. 1 Elms-road, Clapham Common, London, S.W.

1877.§§Newth, A. H., M.D. Hayward's Heath, Sussex.

1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalen College, Cambridge.

1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.

1865. ‡Newton, Thomas Henry Goodwin. Clopton House, near Stratford-on-Avon

1867. ‡Nicholl, Thomas, ex-Dean of Guild. Dundee.

1874.§§Nicholls, H. F. King's-square, Bridgewater, Somerset.

1875. ‡Nicholls, J. F. City Library, Bristol.

1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.

1838. *Nicholson, Cornelius, F.G.S., F.S.A. Wellfield, Muswell Hill, London, N.

1861. *Nicholson, Edward. 88 Mosley-street, Manchester.

1871.§§Nicholson, E. Chambers. Herne Hill, London, S.E.

1867. ‡NICHOLSON, HENRY ALLEYNE, M.D., D.Sc., F.G.S., Professor of Natural History in the University of St. Andrews, N.B.

1850. ‡NICOL, JAMES, F.R.S.E., F.G.S., Professor of Natural History in Marischal College, Aberdeen.

1867. ‡Nimmo, Dr. Matthew. Nethergate, Dundee.

1878. §Niven, C. Queen's College, Cork.

1877. *Niven, James, M.A. Queen's College, Cambridge.

Niven, Ninian. Clonturk Lodge, Drumcondra, Dublin.

'‡Nixon, Randal C. J., M.A. Green Island, Belfast.

1863. *NOBLE, Captain ANDREW, F.R.S., F.R.A.S., F.C.S. Elswick Works, Newcastle-on-Tyne.

1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.

1860. *Nolloth, Rear-Admiral Matthew S., R.N., F.R.G.S. United Service Club, S.W.; and 13 North-terrace, Camberwell, London, S.E.

1859. ‡Norfolk, Richard. Messrs. W. Rutherford and Co., 14 Canada Dock, Liverpool.

1868. Norgate, William. Newmarket-road, Norwich.

1863.§§NORMAN, Rev. ALFRED MERLE, M.A. Burnmoor Rectory, Fence House, Co. Durham.

Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.

1865. ‡NORRIS RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.

1872.§§Norris, Thomas George. Corphwysfa, Llanrwst, North Wales.

1866. †North, Thomas. Cinder-hill, Nottingham.

1869. ‡NORTHCOTE, The Right Hon. Sir STAFFORD H., Bart., C.B., M.P., F.R.S. Pynes, Exeter.

*NORTHWICK, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.

1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of. Norwich.

1861. ‡Noton, Thomas. Priory House, Oldham.

Nowell, John. Farnley Wood, near Huddersfield.

1878. §Nugent, Edward, C.E. Seel's-buildings, Liverpool.

1878. §O'Brien, Murrough. 1 Willow-terrace, Blackrock, Co. Dublin.

O'Callaghan, George. Tallas, Co. Clare.

Year of
Election.
1878. §O'Carroll, Joseph F. 2 Garville-road, Dublin.
1878. §O'Connor Don, The, M.P. Clonalis, Castlerea, Ireland.
Odgers, Rev. William James. Saville House, Weston-road, Bath.
1858. *ODLING, WILLIAM, M.B., F.R.S., F.C.S. Waynflete Professor of Chemistry in the University of Oxford. The Museum, Oxford.
1857. ‡O'Donnavan, William John. Portarlington, Ireland.
1870. O'Donnell, J. O., M.D. 34 Rodney-street, Liverpool.
1877. §Ogden, Joseph. 46 London-wall, London, E.C.
1876. §§Ogilvie, Campbell P. Sizewell House, Leuton, Suffolk.
1859. ‡Ogilvie, C. W. Norman. Baldovan House, Dundee.
*OGILVIE-FORBES, GEORGE, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. Boyndlie, Fraserburgh, N.B.
1874. §Ogilvie, Thomas Robertson. Bank Top, 3 Lyle-street, Greenock, N.B.
1863. ‡Ogilvy, G. R. Inverquharity, N.B.
1863. ‡OGILVY, Sir JOHN. Bart. Inverquharity, N.B.
*Ogle, William, M.D., M.A. The Elms, Derby.
1859. ‡Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.
1837. ‡O'Hagan, John, M.A., Q.C. 22 Upper Fitzwilliam-street. Dublin.
1874. ‡O'HAGAN, The Right Hon. Lord, M.R.I.A. 34 Rutland-square West, Dublin.
1862. ‡O'KELLY, JOSEPH, M.A., M.R.I.A. 14 Hume-street, Dublin.
1853. §OLDHAM, JAMES, C.E. Cottingham, near Hull.
1860. ‡*O'Leary, Professor Purcell, M.A. Queenstown.*
1863. ‡Oliver, Daniel, F.R.S., Professor of Botany in University College, London. Royal Gardens, Kew, Surrey.
1874. ‡O'Meara, Rev. Eugene. Newcastle Rectory, Hazlehatch, Ireland.
*OMMANNEY, Admiral Sir ERASMUS, C.B., F.R.S., F.R.A.S., F.R.G.S. The Towers, Yarmouth, Isle of Wight.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1842. ORMEROD, GEORGE WAREING, M.A., F.G.S. Brookbank, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham Hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1835. ORPEN, JOHN H., LL.D., M.R.I.A. 58 Stephen's-green, Dublin.
1838. ORR, Alexander Smith. 57 Upper Sackville-street, Dublin.
1876. ‡Orr, John B. Granville-terrace, Crosshill, Glasgow.
1873. ‡Osborn, George. 47 Kingscross-street, Halifax.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1877. *Osler, Miss A. F. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham.
1869. *Osler, Sidney F. 1 Pownall-gardens, Hounslow, near London.
1854. ‡Outram, Thomas. Greetland, near Halifax.
OVERSTONE, SAMUEL JONES LLOYD, Lord, F.G.S. 2 Carlton-gardens, London, S.W.; and Wickham Park, Bromley.
1870. ‡Owen, Harold. The Brook Villa, Liverpool.
1857. ‡Owen, James H. Park House, Sandymount, Co. Dublin.
OWEN, RICHARD, C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. M.R.S.E., Director of the Natural-History Department, British Museum. Sheen Lodge, Mortlake, Surrey, S.W.
1877. §§Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

Year of Election.

1859. ‡PAGE, DAVID, LL.D., F.R.S.E., F.G.S. College of Physical Science, Newcastle-upon-Tyne.
1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1875. ‡Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *Palgrave, R. H. Inglis. 11 Britannia-terrace, Great Yarmouth.
1873. ‡Palmer, George. The Acacias, Reading, Berks.
1866. §Palmer, H. 76 Goldsmith-street, Nottingham.
1878. *Palmer, Joseph Edward. Lucan, Co. Dublin.
1866. §Palmer, William. Iron Foundry, Canal-street, Nottingham.
1872. *Palmer, W. R. 376 Coldharbour-lane, Stockwell, S.W.
Palmes, Rev. William Lindsay, M.A. The Vicarage, Hornsea, Hull.
1857. *Parker, Alexander, M.R.I.A. 59 William-street, Dublin.
1863. ‡Parker, Henry. Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
1874. ‡Parker, Henry R., LL.D. Methodist College, Belfast.
Parker, Joseph, F.G.S. Upton Chaney, Bitton, near Bristol.
Parker, Richard. Dunscombe, Cork.
1865. *Parker, Walter Mantel. High-street, Alton, Hants.
Parker, Rev. William. Saham, Norfolk.
1853. ‡Parker, William. Thorton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling. 6 St. Mary's-row, Birmingham.
1864. §§PARKES, WILLIAM. 23 Abingdon-street, Westminster, S.W.
1859. ‡Parkinson, Robert, Ph.D. West View, Toller-lane, Bradford, Yorkshire.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, London, E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N.B.
1877. §Parson, T. Edgcumbe. 36 Torrington-place, Plymouth.
1865. *Parsons, Charles Thomas. Norfolk-road, Edgbaston, Birmingham.
1878. §Parsons, Hon. C. A. 10 Connaught-place, London, W.
1878. §Parsons, Hon. R. C. 10 Connaught-place, London, W.
1875. ‡Pass, Alfred C. 16 Redland Park, Clifton, Bristol.
1855. ‡*Paterson, William. 100 Brunswick-street, Glasgow.*
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A. Henry. 3 Old-buildings, Lincoln's Inn, London, W.C.
1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1876. §Patterson, T. L. Belmont, Margaret-street, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡Pattinson, John. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-upon-Tyne.
1867. §Pattison, Samuel Rowles, F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-street, London, W.
1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.
1877. §Payne, J. C. Charles. Botanic Avenue, Belfast.
1851. ‡*Payne, Joseph. 4 Kildare-gardens, Bayswater, London, W.*
1866. ‡*Payne, Dr. Joseph F. 4 Kildare-gardens, Bayswater, London, W.*
1876. §§Peace, G. H. Morton Grange, Eccles, near Manchester.
1847. †PEACH, CHARLES W., Pres. R.P.S. Edin., A.L.S. 30 Haddington-place, Leith-walk, Edinburgh.

Year of
Election.

1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.
1876. ‡Pearce, W. Elmpark House, Govan, Glasgow.
*Pearsall, Thomas John, F.C.S. Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, W.C.
1875. ‡*Pearson, H. W. Tramore Villa, Nugent Hill, Cotham, Bristol.*
1872. *Pearson, Joseph. Lern Side Works, Nottingham.
1870. ‡Pearson, Rev. Samuel. 48 Prince's-road, Liverpool.
1863. §Pease, H. F. Brinkburn, Darlington.
1863. *Pease, Joseph W., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-on-Tyne.
1858. *Pease, Thomas, F.G.S. Cote Bank, Westbury-on-Trym, near Bristol.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.L.S., F.R.G.S. Harecroft House, Wisbech, Cambridgeshire.
*Peckover, Algernon, F.L.S. Sibald's Holme, Wisbech, Cambridgeshire.
1878. *Peek, William. St. Clair, Hayward's Heath, Sussex.
*Peel, George. Soho Iron Works, Manchester.
1873. ‡Peel, Thomas. 9 Hampton-place, Bradford, Yorkshire.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1861. *Peiser, John. Barnfield House, 491 Oxford-street, Manchester.
1878. §Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, London, W.C.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, John, M.P. 18 Arlington-street, London, S.W.
1868. ‡Pendergast, Thomas. Lancefield, Cheltenham.
1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.
1875. ‡Percival, Rev. J., M.A., LL.D. The College, Clifton, Bristol.
1845. ‡PERCY, JOHN, M.D., F.R.S., F.G.S., Professor of Metallurgy in the Royal School of Mines. Museum of Practical Geology, Jermyn-street, S.W.; and 1 Gloucester-crescent, Hyde Park, London, W.
*Perigal, Frederick. Thatched House Club, St. James's-street, London, S.W.
1868. *PERKIN, WILLIAM HENRY, F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow.
1861. ‡*Perkins, Rev. George. St. James's View, Dickenson-road, Rusholme, near Manchester.*
1877. §Perkins, Loftus. 140 Abbey-road, Kilburn, London, N.W.
Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.
1864. *Perkins, V. R. The Brands, Wotton-under-Edge, Gloucestershire.
1861. ‡*Perring, John Shae. 104 King-street, Manchester.*
Perry, The Right Rev. Charles, M.A., D.D. 32 Avenue-road, Regent's Park, London, N.W.
1874. ‡Perry, John. 5 Falls-road, Belfast.
*Perry, Rev. S. G. F., M.A. Tottington Vicarage, near Bury.
1870. *PERRY, Rev. S. J., F.R.S., F.R.A.S., F.M.S. Stonyhurst College Observatory, Whalley, Blackburn.
1861. *Petrie, John. South-street, Rochdale.
Peyton, Abel. Oakhurst, Edgbaston, Birmingham.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 108 Marina, St. Leonard's-on-Sea.
1867. ‡PHAYRE, Lieut.-General Sir ARTHUR, K.C.S.I., C.B. Governor of Mauritius.

Year of Election.

1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. 35 Church-street, Manchester.
*Philips, Mark. Welcombe, Stratford-on-Avon.
Philips, Robert N. The Park, Manchester.
1863. ‡Philipson, Dr. 1 Savile-row, Newcastle-on-Tyne.
1859. *PHILLIPS, Major-General Sir B. TRAVELL. United Service Club, Pall Mall, London, S.W.
1862. ‡Phillips, Rev. George, D.D. Queen's College, Cambridge.
1872. ‡PHILLIPS, J. ARTHUR. Cressington Park, Aigburth, Liverpool.
1877. §Phillips, T. Wishart. 269 West Ferry-road, London, E.
1868. ‡Phipson, R. M., F.S.A. Surrey-street, Norwich.
1868. ‡PHIPSON, T. L., Ph.D. 4 The Cedars, Putney, Surrey, S.W.
1864. ‡Pickering, William. Oak View, Clevedon.
1861. ‡*Pickstone, William. Radcliff Bridge near Manchester.*
1870.§§Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1870. ‡Pigot, Rev. E. V. Malpas, Cheshire.
1871. ‡Pigot, Thomas F., C.E., M.R.I.A. Royal College of Science, Dublin.
*Pike, Ebenezer. Besborough, Cork.
1865. ‡PIKE, L. OWEN. 25 Carlton-villas, Maida-vale, London, W.
1873. §Pike, W. H. 4 The Grove, Highgate, London, N.
1857. ‡Pilkington, Henry M., M.A., Q.C. 45 Upper Mount-street, Dublin.
1863. *PIM, Captain BEDFORD C. T., R.N., M.P., F.R.G.S. Leaside, Kingswood-road, Upper Norwood, London, S.E.
Pim, George, M.R.I.A. Brenanstown, Cabinteely, Co. Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
1877. §Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
Pim, William H., M.R.I.A. Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrews, Norwich.
1876. ‡Pirie, Rev. G. Queen's College Cambridge.
1859. ‡Pirrie, William, M.D., LL.D. 238 Union-street West, Aberdeen.
1866. ‡Pitcairn, David. Dudhope House, Dundee.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1869. §PLANT, JAMES, F.G.S. 40 West-terrace, West-street, Leicester.
1865. ‡Plant, Thomas L. Camp Hill, and 33 Union-street, Birmingham.
1842. PLAYFAIR, The Right Hon. LYON, C.B., Ph.D., LL.D., M.P., F.R.S.L. & E., F.C.S. 68 Onslow-gardens, South Kensington, London, S.W.
1867. ‡PLAYFAIR, Lieut.-Colonel R. L., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *POCHIN, HENRY DAVIS, F.C.S. Bodnant Hall, near Conway.
1846. ‡POLE, WILLIAM, Mus. Doc., F.R.S., M.I.C.E. Athenæum Club, Pall Mall, London, S.W.
* Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1854. ‡Poole, Braithwaite. Birkenhead.
1868. ‡*Pooley, Thomas A., B.Sc. South Side, Clapham Common, London, S.W.*
1868. ‡Portal, Wyndham S. Malsanger, Basingstoke.
1874. ‡Porter, Rev. J. Leslie, D.D., LL.D. College Park, Belfast.

Year of
Election.

1866. §Porter, Robert. Beeston, Nottingham.
Porter, Rev. T. H., D.D., M.R.I.A. Tullyhogue, Co. Tyrone.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
*POTTER, EDMUND, F.R.S. Camfield-place, Hatfield, Herts.
1842. Potter, Thomas. George-street, Manchester.
1863. ‡Potts, James. 26 Sandhill, Newcastle-on-Tyne.
1857. *POUNDEN, Captain LONSDALE, F.R.G.S. Junior United Service Club, St. James's-square, London, S.W.; and Brownswood House, Enniscorthy, Co. Wexford.
1873. *Powell, Francis S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1857. ‡Power, Sir James, Bart. Edermine, Enniscorthy, Ireland.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuck, Uddingstone, Hamilton, Scotland.
1869. *Preece, William Henry. Gothic Lodge, Wimbledon Common, London, S.W.
Prest, The Venerable Archdeacon Edward. The College, Durham.
*PRESTWICH, JOSEPH, M.A., F.R.S., F.G.S., F.C.S., Professor of Geology in the University of Oxford. 34 Broad-street, Oxford; and Shoreham, near Sevenoaks.
1871. ‡Price, Astley Paston. 47 Lincoln's-Inn-Fields, London, W.C.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford. 11 St. Giles's, Oxford.
1872. ‡Price, David S., Ph.D. 26 Great George-street, Westminster, S.W.
Price, J. T. Neath Abbey, Glamorganshire.
1875. *Price, Rees. 54 Loftus-road, Shepherd's Bush, London, W.
1870. *Price, Captain W. E., M.P., F.G.S. Tibberton Court, Gloucester.
1875. *Price, William Philip. Tibberton Court, Gloucester.
1876. §§Priestley, John. Lloyd-street, Greenheys, Manchester.
1875. ‡Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1835. *Pritchard, Andrew, F.R.S.E. 87 St. Paul's-road, Canonbury, London, N.
1846. *PRITCHARD, Rev. CHARLES, M.A., F.R.S., F.G.S., F.R.A.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1872. ‡Pritchard, Rev. W. Gee. Brignal Rectory, Barnard Castle, Co. Durham.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 3 George-street, Hanover-square, London, W.
1863. ‡Proctor, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, Thomas. Elmsdale House, Clifton Down, Bristol.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1858. §Proctor, William, M.D., F.C.S. 24 Petergate, York.
1863. *Prosser, Thomas. West Boldon, Newcastle-on-Tyne.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1865. ‡Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.
1872. *Pryor, M. Robert. Western Manor, Stevenage, Herts.
1871. *Puckle, Thomas John. Woodcote-grove, Carshalton, Surrey.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. ‡Pullar, John. 4 St. Leonard Bank, Perth.
1867. *Pullar, Robert. 6 St. Leonard Bank, Perth.

Year of Election.

1842 *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.

Punnet, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.

1852. ‡Purdon, Thomas Henry, M.D. Belfast.

1860. ‡PURDY, FREDERICK, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.

1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.

1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College, Belfast.

1878. §Purser, John Mallet. 3 Wilton-terrace, Dublin.

1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.

1868. §PYE-SMITH, P. H., M.D. 56 Harley-street, W.; and Guy's Hospital, London, S.E.

1861. *Pyne, Joseph John. St. German's Villa, St. Lawrence-road, Notting Hill, London, W.

1870. ‡Rabbits, W. T. Forest Hill, London, S.E.

1860. ‡RADCLIFFE, CHARLES BLAND, M.D. 25 Cavendish-square, London, W.

1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.

1877. §§Radford, George D. Mannamead, Plymouth.

*Radford, William, M.D. Sidmount, Sidmouth.

1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.

1870. ‡Raffles, William Winter. Sunnyside, Prince's Park, Liverpool.

1864. ‡Rainey, James T. St. George's Lodge, Bath.

Rake, Joseph. Charlotte-street, Bristol.

1863. ‡RAMSAY, ALEXANDER, F.G.S. Kilmorey Lodge, 6 Kent-gardens, Ealing, W.

1845. †RAMSAY, ANDREW CROMBIE, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of the United Kingdom and of the Museum of Economic Geology. Geological Survey Office, Jermyn-street, London, S.W.

1867. ‡Ramsay, James, jun. Dundee.

1861. ‡Ramsay, John, M.P. Kildalton, Argyleshire.

1867. *Ramsay, W. F., M.D. 61 Overstone-road, Hammersmith, London, W.

1876. ‡Ramsay, William, Ph.D. 11 Ashton-terrace, Glasgow.

1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford, Yorkshire.

1835. *Rance, Henry (Solicitor). Cambridge.

1869. *Rance, H. W. Henniker, LL.M. 62 St. Andrew's-street, Cambridge.

1860. ‡Randall, Thomas. Grandepoint House, Oxford.

1865. ‡Randel, J. 50 Vittoria-street, Birmingham.

1855. ‡*Randolph, Charles. Pollockshiels, Glasgow.*

Ranelagh, The Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.

1868. *Ransom, Edwin, F.R.G.S. Kempstone Mill, Bedford.

1863. §Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.

1861. ‡Ransome, Arthur, M.A. Bowdon, Manchester.

Ransome, Thomas. 34 Princess-street, Manchester.

1872. *Ranyard, Arthur Cowper, F.R.A.S. 25 Old-square, Lincoln's Inn, London, W.C.

Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.

RATCLIFF, Colonel CHARLES, F.L.S., F.G.S., F.S.A., F.R.G.S. Wyddrington, Edgbaston, Birmingham.

1864. ‡Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.

1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.

1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.

1870. §Rathbone, R. R. Beechwood House, Liverpool.

Year of Election.

1863. ‡Rattray, W. St. Clement's Chemical Works, Aberdeen.
1874. ‡Ravenstein, E. G., F.R.G.S. 10 Lorn-road, Brixton, London, S.W.
Rawdon, William Frederick, M.D. Bootham, York.
1870. ‡Rawlins, G. W. The Hollies, Rainhall, Liverpool.
*Rawlins, John. Shrawley Wood House, near Stourport.
1866. *Rawlinson, Rev. Canon George, M.A., Camden Professor of Ancient History in the University of Oxford. The Oaks, Precincts, Canterbury.
1855. *Rawlinson, Major-General Sir Henry C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1875. §Rawson, Sir Rawson W., K.C.M.G., C.B. Drayton House, West Drayton, Middlesex.
1868. *Rayleigh, The Right Hon. Lord, M.A., F.R.S., F.R.G.S. 4 Carlton-gardens, Pall Mall, London, S.W.; and Terling Place, Witham, Essex.
1865. ‡*Rayner, Henry. West View, Liverpool-road, Chester.*
1870. ‡Rayner, Joseph (Town Clerk). Liverpool.
1852. ‡Read, Thomas, M.D. Donegal-square West, Belfast.
1865. ‡Read, William. Albion House, Epworth, Bawtry.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. §Reade, Thomas Mellard, C.E., F.G.S. Blundellsands, Liverpool.
1862. *Readwin, Thomas Allison, M.R.I.A., F.G.S. 28 Bold-street, Alexandra-road, Manchester.
1852. *Redfern, Professor Peter, M.D. 4 Lower-crescent, Belfast.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1863. ‡Redmayne, R. R. 12 Victoria-terrace, Newcastle-on-Tyne.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. ‡Reed, Edward J., C.B., M.P., F.R.S. 74 Gloucester-road, South Kensington, London, W.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1876. §§Reid, James. 10 Woodside-terrace, Glasgow.
1874. ‡Reid, Robert, M.A. 35 Dublin-road, Belfast.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1875. §Reinold, A. W., M.A., Professor of Physical Science. Royal Naval College, Greenwich, S.E.
1863. §Renals, E. 'Nottingham Express' Office, Nottingham.
1863. ‡Rendel, G. Benwell, Newcastle-on-Tyne.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1871. ‡Reynolds, James Emerson, M.A., F.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *Reynolds, Osborne, M.A., F.R.S., Professor of Engineering in Owens College, Manchester. Fallowfield, Manchester.
1858. §Reynolds, Richard, F.C.S. 13 Briggate, Leeds.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1877. §Rhodes, John. 358 Blackburn-road, Accrington, Lancashire.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Via Stimmate, 15, Modena, Italy.
1868. §§Richards, Vice-Admiral Sir George H., C.B., F.R.S., F.R.G.S. The Athenæum Club, London, S.W.
1863. ‡Richardson, Benjamin Ward, M.A., M.D., F.R.S. 12 Hinde-street, Manchester-square, London, W.
1861. §§Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. Albert Park, Abingdon, Berks.
1863. *Richardson, Edward. 6 Stanley-terrace, Gosforth, Newcastle-on-Tyne.

Year of Election.

1868. *Richardson, George. 4 Edward-street, Werneth, Oldham.
1870. ‡Richardson, J. H. 3 Arundel-terrace, Cork.
1870. ‡Richardson, Ralph. 16 Coates-crescent, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
1861. ‡Richardson, William. 4 Edward-street, Werneth, Oldham.
1876. §§Richardson, William Haden. City Glass Works, Glasgow.
1861. ‡*Richson, Rev. Canon, M.A. Shakespeare-street, Ardwick, Manchester.*
1863. ‡Richter, Otto, Ph.D. 6 Derby-terrace, Glasgow
1870. ‡Rickards, Dr. 36 Upper Parliament-street, Liverpool.
1868. §RICKETTS, CHARLES, M.D., F.G.S. 22 Argyle-street, Birkenhead.
1877. §§Ricketts, James, M.D. St. Helen's, Lancashire.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1861. *Riddell, Henry B. Whitefield House, Rothbury, Morpeth.
1872. ‡Ridge, James. 98 Queen's-road, Brighton.
1862. ‡Ridgway, Henry Ackroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1863. *Rigby, Samuel. Bruche Hall, Warrington.
1873. ‡Ripley, Edward. Acacia, Apperley, near Leeds.
1873. §§Ripley, H. W. Acacia, Apperley, near Leeds.
*RIPON, The Most Hon. the Marquis of, K.G., D.C.L., F.R.S., F.L.S., F.R.G.S. 1 Carlton-gardens, London, S.W.
1860. ‡*Ritchie, George Robert. 4 Watkyn-terrace, Coldharbour-lane, Camberwell, London, S.E.*
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡Ritchie, Robert, C.E. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1869. *Rivington, John. Babbicombe, near Torquay.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *ROBBINS, JOHN, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
Roberton, John. Oxford-road, Manchester.
1878. §Roberts, Charles, F.R.C.S. 2 Bolton-row, London, W.
1859. ‡Roberts, George Christopher. Hull.
1859. ‡Roberts, Henry, F.S.A. Athenæum Club, London, S.W.
1870. *Roberts, Isaac, F.G.S. Kennessee, Maghull, Lancashire.
1857. ‡Roberts, Michael, M.A. Trinity College, Dublin.
1868. §ROBERTS, W. CHANDLER, F.R.S., F.G.S., F.C.S. Royal Mint, London, E.
1866. ‡*Robertson, Alister Stuart, M.D., F.R.G.S. Horwich, Bolton, Lancashire.*
1876. ‡Robertson, Andrew Carrick. Woodend House, Helensburgh, N.B.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1867. §Robertson, David. Union Grove, Dundee.
1871. ‡Robertson, George, C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1870. *Robertson, John. Lyme View, Whalley Range, Manchester.
1876. ‡*Robertson, R. A. 9 Queen's-square, Regent Park, Glasgow.*
1866. ‡ROBERTSON, WILLIAM TINDAL, M.D. Nottingham.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Tartaraghan Glebe, Loughgall, Ireland.
1859. ‡Robinson, Hardy. 156 Union-street, Aberdeen.
*Robinson, H. Oliver. 34 Bishopsgate-street, London, E.C.
1873. §Robinson, Hugh. 82 Donegall-street, Belfast.
1861. ‡Robinson, John. Atlas Works, Manchester.
1863. ‡Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.

Year of Election.

1878. §Robinson, John L., C.E. 198 Great Brunswick-street, London, W.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1875. *Robinson, Robert, C.E. 2 West-terrace, Darlington.
1860. ‡Robinson, Admiral Sir Robert Spencer, K.C.B., F.R.S. 61 Eaton-place, London, S.W.
ROBINSON, Rev. THOMAS ROMNEY, D.D., F.R.S., F.R.A.S., Hon. F.R.S.E., M.R.I.A., Director of the Armagh Observatory. Armagh.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. ‡Robinson, William. 40 Smithdown-road, Liverpool.
1870. *Robson, E. R. 41 Parliament-street, Westminster, S.W.
1876.§§Robson, Hazleton R. 14 Royal-crescent West, Glasgow.
**Robson, Rev. John, M.A., D.D. Ajmere Lodge, Cathkin-road, Langside, Glasgow.*
1855. ‡Robson, Neil, C.E. 127 St. Vincent-street, Glasgow.
1872. *Robson, William. Marchholm, Gillsland-road, Merchiston, Edinburgh.
1872. §RODWELL, GEORGE F., F.R.A.S., F.C.S. Marlborough College, Wiltshire.
1866. ‡Roe, Thomas. Grove-villas, Sitchurch.
1861. ‡ROFE, JOHN, F.G.S. 9 Crosbie-terrace, Leamington.
1860. ‡ROGERS, JAMES E. THOROLD, Professor of Economic Science and Statistics in King's College, London. Beaumont-street, Oxford.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1869. *Rogers, Nathaniel, M.D. 87 South-street, Exeter.
1870. ‡Rogers, T. L., M.D. Rainhill, Liverpool.
1859. ‡ROLLESTON, GEORGE, M.A., M.D., F.R.S., F.L.S., Professor of Anatomy and Physiology in the University of Oxford. The Park, Oxford.
1876. §Rollit, A. K., B.A., LL.D., F.R.A.S. The Literary and Philosophical Society, Hull.
1866. ‡Rolph, George Frederick. War Office, Horse Guards, London, S.W.
1876. ‡Romanes, George John, M.A., F.L.S. 18 Cornwall-terrace, Regent's Park, London, N.W.
1863. ‡*Romilly, Edward. 14 Hyde Park-terrace, London, W.*
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. *Roper, Freeman Clarke Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1855. *ROSCOE, HENRY ENFIELD, B.A., Ph.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
1863. ‡Roseby, John. Haverholm House, Brigg, Lincolnshire.
1874. ‡Ross, Alexander Milton, M.A., M.D., F.G.S. Toronto, Canada.
1857. ‡Ross, David, LL.D. 32 Nelson-street, Dublin.
1872. ‡Ross, James, M.D. Tenterfield House, Waterfoot, near Manchester.
1859. *Ross, Rev. James Coulman. Baldon Vicarage, Oxford.
1874. ‡Ross, Rev. William. Chapelhill Manse, Rothesay, Scotland.
1869. *ROSSE, The Right Hon. the Earl of, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland; and 32 Lowndes-square, London, S.W.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1876.§§Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1861. ‡Routh, Edward J., M.A., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.

Year of Election.

1872. *Row, A. V. Nursing Observatory, Daba-gardens, Vizagapatam, India. (Care of Messrs. King & Co., 45 Pall Mall, London, S.W.)
1861. ‡Rowan, David. Elliot-street, Glasgow.
1876. ‡Rowan, David. 22 Woodside-place, Glasgow.
1877. §Rowe, J. Brooking, F.L.S. 16 Lockyer-street, Plymouth.
1865. §Rowe, Rev. John. Load Vicarage, Langport, Somerset.
1855. *Rowney, Thomas H., Ph.D., F.C.S., Professor of Chemistry in Queen's College Galway. Salerno, Salthill, Galway.
*Rowntree, Joseph. 12 Heslington-road, York.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1861. *Royle, Peter, M.D., L.R.C.P., M.R.C S. 27 Lever-street, Manchester.
1875. ‡Rücker, A. W., M.A., Professor of Mathematics and Physics in the Yorkshire College, Leeds.
1869. §Rudler, F. W., F.G.S. Professor of Chemistry and Mineralogy in University College, Aberystwith.
1873. ‡Rushforth, Joseph. 43 Ash-grove, Horton-lane, Bradford, Yorkshire.
1847. ‡Ruskin, John, M.A., F.G.S., Slade Professor of Fine Arts in the University of Oxford. Corpus Christi College, Oxford.
1857. ‡Russell, The Very Rev. C. W., D.D., M.R.I.A. Maynooth College.
1875. *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.
1876. *Russell, George. 103 Blenheim-crescent, Notting Hill, London, W.
1865. ‡Russell, James, M.D. 91 Newhall-street, Birmingham.
Russell, John. 39 Mountjoy-square, Dublin.
Russell, John Scott, M.A., F.R.S. L. & E. Sydenham, S.E.; and 5 Westminster-chambers, London, S.W.
1852. *Russell, Norman Scott. 5 Westminster-chambers, London, S.W.
1876. §Russell, R., C.E., F.G.S. 1 Sea View, St. Bees, Carnforth.
1862. §Russell, W. H. L., A.B., F.R.S. 5 The Grove, Highgate, London, N.
1852. *Russell, William J., Ph.D., F.R.S., F.C.S , Professor of Chemistry, St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1875. §§Rutherford, David Greig. Surrey House, Forest Hill, London, S.E.
1871. §Rutherford, William, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1875. ‡Ryalls, Charles Wager, LL D. 3 Brick-court, Temple, London, E.C.
1874. §Rye, E. C., F.Z.S., Librarian R.G.S. 70 Charlewood-road, Putney, S.W.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *Rylands, Thomas Glazebrook, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

*Sabine, General Sir Edward, K.C.B., R.A., LL.D., D C.L., F.R S., F.R.A.S., F.L.S., F.R.G.S. 13 Ashley-place, Westminster, S.W.
1865. ‡*Sabine, Robert. Auckland House, Willesden-lane, London, N.W.*
1871. §Sadler, Samuel Champernowne. Purton Court, Purton, near Swindon, Wiltshire.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
Salkeld, Joseph. Penrith, Cumberland.

Year of
Election.

1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.
1873. *Salomons, Sir David, Bart. Broomhill, Tunbridge Wells.
1872. ‡SALVIN, OSBERT, M.A., F.R.S., F.L.S. Brookland Avenue, Cambridge.
1842. Sambrooke, T. G. 32 Eaton-place, London, S.W.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1867. ‡*Samuelson, Edward. Roby, near Liverpool.*
1870. ‡*Samuelson, James. St. Domingo-grove, Everton, Liverpool.*
1861. *Sandeman, Archibald, M.A. Tulloch, Perth.
1876. §Sandeman, David. Woodlands, Lenzie, Glasgow.
1878. §Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1857. ‡Sanders, Gilbert. The Hill, Monkstown, Co. Dublin.
1872. ‡Sanders, Mrs. 8 Powis-square, Brighton.
1871. ‡Sanders, William R., M.D. 11 Walker-street, Edinburgh.
1872 §§SANDERSON, J. S. BURDON, M.D., F.R.S., Professor of Physiology in University College, London. 49 Queen Anne-street, London, W.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. ‡Sandford, William. 9 Springfield-place, Bath.
1854. ‡Sandon, The Right Hon. Lord, M.P. 39 Gloucester-square, London, W.
1873. ‡Sands, T. C. 24 Spring-gardens, Bradford, Yorkshire.
1865. ‡Sargant, W. L. Edmund-street, Birmingham.
1868. ‡Saunders, A., C.E King's Lynn.
1846. ‡SAUNDERS, TRELAWNEY W. India Office, London, S.W.
1864. ‡Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.
1860. *Saunders, William. 3 Gladstone-terrace, Brighton.
1871. §Savage, W. D. Ellerslie House, Brighton.
1863. ‡*Savory, Valentine. Cleckheaton, near Leeds.*
1872. *Sawyer, George David. 55 Buckingham-place, Brighton.
1868. ‡Sawyer, John Robert. Grove-terrace, Thorpe Hamlet, Norwich.
1850. ‡*Scarth, Pillans. 2 James's-place, Leith.*
1863. §Schacht, G. F. 7 Regent's-place, Clifton, Bristol.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1874. §Scholefield, Henry. Windsor-crescent, Newcastle-on-Tyne.
*Scholes, T. Seddon. 10 Warwick-place, Leamington.
1876. §§Schuman, Sigismond. 7 Royal Bank-place, Glasgow.
SCHUNCK, EDWARD, F.R.S., F.C.S. Oaklands, Kersall Moor, Manchester.
1873. *SCHUSTER, ARTHUR, Ph.D. Sunnyside, Upper Avenue-road, Regent's Park, London, N.W.
1861. *Schwabe, Edmund Salis. Ryecroft House, Cheetham Hill, Manchester.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., Sec. Zool. Soc. (GENERAL SECRETARY.) 11 Hanover-square, London, W.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1878. §Scott, Arthur William. St. David's College, Lampeter.
1876. ‡Scott, Mr. Bailie. Glasgow.
1871. ‡Scott, Rev. C. G. 12 Pilrig-street, Edinburgh.
1876. ‡*Scott, D. D. Glasgow.*
1872. ‡Scott, Major-General H. Y. D., C.B., R.E., F.R.S. Sunnyside, Ealing, W.
1871. ‡Scott, James S. T. Monkrigg, Haddingtonshire.
1857. *SCOTT, ROBERT H., M.A., F.R.S., F.G.S., F.M.S., Secretary to the Council of the Meteorological Office. 116 Victoria-street, London, S.W.

Year of Election.

1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1874. ‡Scott, Rev. Robinson, D.D. Methodist College, Belfast.
1864. ‡Scott, Wentworth Lascelles. Wolverhampton.
1858. ‡Scott, William. Holbeck, near Leeds.
1869. §Scott, William Bower. Chudleigh, Devon.
1859. ‡Seaton, John Love. Hull.
1877.§§Seaton, Robert Cooper, B.A. Dulwich College, Dulwich, Surrey, S.E.
1861. *SEELEY, HARRY GOVIER, F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geography in King's College, London. 61 Adelaide-road, South Hampstead, London, N.W.
1855. ‡Seligman, H. L. 135 Buchanan-street, Glasgow.
1873. ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.
1858. *Senior, George, F.S.S. Rosehill Lodge, Dodworth, near Barnsley.
1870. *Sephton, Rev. J. 92 Huskisson-street, Liverpool.
1875. §Seville, Thomas. Elm House, Royton, near Manchester.
1873.§§Sewell, Rev. E., M.A., F.G.S., F.R.G.S. Ilkley College, near Leeds.
1868. ‡Sewell, Philip E. Catton, Norwich.
1861. *Seymour, Henry D. 209 Piccadilly, London, W.
1853. ‡*Shackles, G. L. 6 Albion-street, Hull.*
*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, W.
1871. *Shand, James. Fullbrooks, Worcester Park, Surrey.
1867. §Shanks, James. Den Iron Works, Arbroath, N.B.
1869. *Shapter, Dr. Lewis, LL.D. The Barnfield, Exeter.
1878. §Sharp, David. Thornhill, Dumfriesshire.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1861. ‡SHARP, SAMUEL, F.G.S., F.S.A. Great Harrowden Hall, near Wellingborough.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
SHARPEY, WILLIAM, M.D., LL.D., F.R.S. L. & E. 50 Torrington-square, London, W.C.
1858. *Shaw, Bentley. Woodfield House, Huddersfield.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. ‡Shaw, Duncan. Cordova, Spain,
1865. ‡Shaw, George. Cannon-street, Birmingham.
1870. ‡Shaw, John. 24 Great George-place, Liverpool.
1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1853. ‡Shaw, Norton, M.D. St. Croix, West Indies.
1839. Shepard, John. 41 Drewton-street, Manningham-road, Bradford, Yorkshire.
1863. ‡Shepherd, A. B. 49 Seymour-street, Portman-square, London, W.
1870. §Shepherd, Joseph. 29 Everton-crescent, Liverpool.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1878. §Shelford, W., C.E. Great George-street, Westminster, S.W.
1866. ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. ‡Shinn, William C. Her Majesty's Printing Office, near Fetter-lane, London, E.C.
1870. *SHOOLBRED, JAMES N., C.E., F.G.S. 3 Westminster-chambers, London, S.W.
1875.§§Shore, Thomas W., F.C.S. Hartley Institution, Southampton.
1861. *Sidebotham, Joseph. The Beeches, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. The Beeches, Bowdon, Cheshire.

Year of
Election.

1873. ‡Sidgwick, R. H. The Raikes, Skipton.
1857. ‡Sidney, Frederick John, LL.D., M.R.I.A. 19 Herbert-street, Dublin.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 12 Queen Anne's-gate, Westminster, S.W.
1856. *SIEMENS, C. WILLIAM, D.C.L., F.R.S., F.C.S., M.I.C.E. 12 Queen Anne's-gate, Westminster, S.W.
1878. §Sigerson, Professor George, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1865. ‡Simkiss, T. M. Wolverhampton.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1874. §Simms, William. The Linen Hall, Belfast.
1876. §§Simon, Frederick. 24 Sutherland-gardens, London, W.
1847. ‡Simon, John, C.B., D.C.L., F.R.S., F.R.C.S., Medical Officer of the Privy Council. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
1876. §§Simpson, Robert. 14 Ibrox-terrace, Glasgow.
*Simpson, Rev. Samuel. Kingston House, Chester.
Simpson, William. Bradmore House, Hammersmith, London, W.
1859. ‡Sinclair, Alexander. 133 George-street, Edinburgh.
1876. ‡Sinclair, James. Titwood Bank, Pollockshields, near Glasgow.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1834. ‡Sinclair, Vetch, M.D. 48 Albany-street, Edinburgh.
1870. *Sinclair, W. P. 19 Devonshire-road, Prince's Park, Liverpool.
1864. *Sircar, Mahendra Lal, M.D. 51 Sankaritola, Calcutta. (Care of Messrs. S. Harraden & Co., 3 Hill's-place, Oxford-street, London, W.)
1865. ‡Sissons, William. 92 Park-street, Hull.
1870. §Sladen, Walter Percy, F.G.S., F.L.S. Exley House, near Halifax.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1870. ‡Slater, W. B. 42 Clifton Park-avenue, Belfast.
1842. *Slater, William. Park-lane, Higher Broughton, Manchester.
1853. ‡*Sleddon, Francis. 2 Kingston-terrace, Hull.*
1877. §Sleeman, Rev. Philip. Clifton, Bristol.
1849. ‡Sloper, George Edgar. Devizes.
1849. ‡Sloper, Samuel W. Devizes.
1860. §Sloper, S. Elgar. Winterton, near Hythe, Southampton.
1872. ‡Smale, The Hon. Sir John, Chief Justice of Hong Kong.
1867. ‡Small, David. Gray House, Dundee.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1876. ‡Smeiton, James. Panmure Villa, Broughty Ferry, Dundee.
1876. ‡Smeiton, John G. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smeiton, Thomas A. 55 Cowgate, Dundee.
1876. §Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. §§Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1857. ‡Smith, Aquilla, M.D., M.R.I.A. 121 Lower Baggot-street, Dublin.

Year of Election.

1868. ‡Smith, Augustus. Northwood House, Church-road, Upper Norwood, Surrey, S.E.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead-Heath, London, N.W.
1874. *Smith, Benjamin Leigh. 64 Gower-street, London, W.C.
1873. ‡Smith, C. Sidney College, Cambridge.
1865. ‡SMITH, DAVID, F.R.A.S. 40 Bennett's-hill, Birmingham.
1865. ‡Smith, Frederick. The Priory, Dudley.
1866. *Smith, F. C., M.P. Bank, Nottingham.
1855. ‡Smith, George. Port Dundas, Glasgow.
1876. ‡Smith, George. Glasgow.
1855. ‡Smith, George Cruickshank. 19 St. Vincent-place, Glasgow.
*SMITH, HENRY JOHN STEPHEN, M.A., F.R.S., F.C.S., Savilian Professor of Geometry in the University of Oxford, and Keeper of the University Museum. The Museum, Oxford.
1860. *Smith, Heywood, M.A., M.D. 2 Portugal-street, Grosvenor-square, London, W.
1876. ‡*Smith, J. Glasgow.*
1870. ‡Smith, James. 146 Bedford-street South, Liverpool.
1871. *Smith, John Alexander, M.D., F.R.S.E. 10 Palmerston-place, Edinburgh.
1876. *Smith, J. Guthrie. 173 St. Vincent-street, Glasgow.
1874. ‡Smith, John Haigh. Beech Hill, Halifax, Yorkshire.
1867. *Smith, John P., C E. Haughhead Cottage, Glasgow.
Smith, John Peter George. Sweyney Cliff, near Coalport, Shropshire.
1871. ‡Smith, Professor J. William Robertson. Free Church College, Aberdeen.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
*Smith, Philip, B.A. 26 South Hill Park, Hampstead, London, N.W.
1860. *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1847. §SMITH, ROBERT ANGUS, Ph.D., F.R S., F.C.S. 22 Devonshire-street, Manchester.
*Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. ‡Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hessle, near Hull.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton, Bristol.
1876. §Smith, William. 12 Woodside-place, Glasgow.
1878. §Smithson, Joseph S. Balnagowan, Rathmines, Co. Dublin.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. *SMYTH, CHARLES PIAZZI, F R S.E., F.R A.S , Astronomer Royal for Scotland, Professor of Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.
1874. ‡Smyth, Henry. C.E. Downpatrick, Ireland.
1870. ‡Smyth, Colonel H. A., R.A. Barrackpore, near Calcutta.
1857. *SMYTH, JOHN, jun., M.A., C.E., F.M.S. Lenaderg, Banbridge, Ireland.
1868. ‡*Smyth, Rev. J. D. Hurst. 13 Upper St. Giles's-street, Norwich.*

Year of
Election.

1864. ‡SMYTH, WARINGTON W., M.A., F.R.S., F.G.S., F.R.G.S., Lecturer on Mining and Mineralogy at the Royal School of Mines, and Inspector of the Mineral Property of the Crown. 5 Inverness-terrace, Bayswater, London, W.
1878. §Smyth, Mrs. Wigmore Lodge, Cullenswood-avenue, Dublin.
1854. ‡Smythe, Lieut.-General W. J., R.A., F.R.S. Athenæum Club, Pall Mall, London, S.W.
1878. §Snell, H. Saxon. 3 Greville-place, Maida Hill, London, N.W.
Soden, John. Athenæum Club, Pall Mall, London, S.W.
*SOLLY, EDWARD, F.R.S., F.L.S., F.G.S., F.S.A. Park House, Sutton, Surrey.
*SOPWITH, THOMAS, M.A., F.R S., F.G.S., F.R.G.S. 103 Victoria-street, Westminster, S.W.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *SORBY, H. CLIFTON, F.R.S., F.G.S. Broomfield, Sheffield.
1865. *Southall, John Tertius. Leominster.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1856. ‡Southwood, Rev. T. A. Cheltenham College.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1863. *Spark, H. King. Starforth House, Barnard Castle.
1859. ‡*Spence, Rev. James, D.D. 6 Clapton-square, London, N.E.*
*Spence, Joseph. 60 Holgate Hill, York.
1869. *Spence, J. Berger. Erlington House, Manchester.
1854. §Spence, Peter. Pendleton Alum Works, Newton Heath; and Smedley Hall, near Manchester.
1861. ‡Spencer, John Frederick. 28 Great George-street, London, S.W.
1861. *Spencer, Joseph. Springbank, Old Trafford, Manchester.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1875. ‡Spencer, W. H. Richmond Hill, Clifton, Bristol.
1871. ‡*Spicer, George. Broomfield, Halifax.*
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1864. §§Spicer, William R. 19 New Bridge-street, Blackfriars, London, E.C.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, London, N.
1878. §Spottiswoode, George Andrew. 29 Ashley-place, London, S.W.
1846. *SPOTTISWOODE, WILLIAM, M.A., D.C.L., LL.D., Pres. R.S., F.R.A.S., F.R.G.S. (PRESIDENT.) 41 Grosvenor-place, London, S.W.
1864. *Spottiswoode, W. Hugh. 41 Grosvenor-place, London, S.W.
1854. *SPRAGUE, THOMAS BOND. 29 Buckingham-terrace, Edinburgh.
1853. ‡Spratt, Joseph James. West Parade, Hull.
Square, Joseph Elliot, F.G.S. 24 Portland-place, Plymouth.
1877. §§SQUARE, WILLIAM, F.R.C.S., F.R.G.S. 4 Portland-square, Plymouth.
*Squire, Lovell. The Observatory, Falmouth.
1858. *STAINTON, HENRY T., F.R.S., F.L.S., F.G.S. Mountsfield, Lewisham, S.E.
1865. §STANFORD, EDWARD C. C. Thornloe, Partick Hill, near Glasgow.
1837. Staniforth, Rev. Thomas. Storrs, Windermere.
STANLEY, The Very Rev. ARTHUR PENRHYN, D.D., F.R.S., Dean of Westminster. The Deanery, Westminster, London, S.W.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1866. ‡Starey, Thomas R. Daybrook House, Nottingham.
1876. §Starling, John Henry, F.C.S. The Avenue, Erith, Kent.
Staveley, T. K. Ripon, Yorkshire.
1873. *Stead, Charles. Saltaire, Bradford, Yorkshire.

Year of Election.

1857. ‡Steale, William Edward, M D. 15, Hatch-street, Dublin.
1870. ‡Stearn, C. H. 2 St. Paul's-villas, Rock Ferry, Liverpool.
1863. ‡Steele, Rev. Dr. 35 Sydney-buildings, Bath.
1873. §Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1861. †Steinthal, H. M. Hollywood, Fallowfield, near Manchester.
STENHOUSE, JOHN, LL D., F.R.S., F.C.S. 17 Rodney-street, Pentonville, London, N.
1872. ‡Stennett, Mrs. Eliza. 2 Clarendon-terrace, Brighton.
1861. *Stern, S. J. Littlegrove, East Barnet, Herts.
1863. §§Sterriker, John. Driffield, Yorkshire.
1872. ‡Sterry, William. Union Club, Pall Mall, London, S.W.
1876. ‡Steuart, Walter. City Bank, Pollockshaws, near Glasgow.
1870. *Stevens, Miss Anna Maria. Belmont, Devizes-road, Salisbury.
1861. *Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London, W.C.
1863. *Stevenson, Archibald. 2 Wellington-crescent, South Shields.
1868. ‡Stevenson, Henry, F.L S. Newmarket-road, Norwich.
1878. §Stevenson, Rev. James, M.A. 21 Garville-avenue, Rathgar, Dublin.
1863. *STEVENSON, JAMES C., M.P., F.C S. Westoe, South Shields.
1876. *Stewart, Alexander B. Rawcliffe Lodge, Langside, Glasgow.
1855. ‡STEWART, BALFOUR, M.A., LL.D., F.R.S., Professor of Natural Philosophy in Owens College, Manchester.
1864. ‡STEWART, CHARLES, M.A., F.L.S. St. Thomas's Hospital, London, S.E.
1856. *Stewart, Henry Hutchinson, M.D., M.R.I.A. 75 Eccles-street, Dublin.
1875. *Stewart, James, B.A. Mount Hope, Sneyd Park, near Bristol.
1847. ‡Stewart, Robert, M.D. The Asylum, Belfast.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1868. ‡Stirling, Edward. 34 Queen's-gardens, Hyde Park, London, W.
1876. ‡Stirling, William, M.D., D.Sc. The University, Edinburgh.
1867. *Stirrup, Mark, F.G.S. 14 Atkinson-street, Deansgate, Manchester.
1865. *Stock, Joseph S. 1 Chartham-terrace, Ramsgate.
1864. §STODDART, WILLIAM WALTER, F.G.S., F.C.S. Grafton Lodge, Sneyd Park, Bristol.
1854. †Stoess, Le Chevalier Ch. de W. (Bavarian Consul). Liverpool.
*STOKES, GEORGE GABRIEL, M.A., D.C.L., LL.D., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1862. ‡STONE, EDWARD JAMES, M.A., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1874. §Stone, J. Harris, B.A., F.L.S., F.C.S. 16 Wilmot-terrace, Belfast.
1876. ‡Stone, Octavius C., F.R.G.S. Springfield, Nuneaton.
1859. ‡Stone, Dr. William H. 14 Dean's-yard, Westminster, S.W.
1857. ‡STONEY, BINDON B., C.E., M.R.I.A., Engineer of the Port of Dublin. 42 Wellington-road, Dublin.
1878. *Stoney, G. Gerald. 8 Palmerston Park, Dublin.
1861. *STONEY, GEORGE JOHNSTONE, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. 3 Palmerston Park, Dublin.
1876. §Stopes, Henry, F.G.S. East Hill, Colchester.
1854. Store, George. Prospect House, Fairfield, Liverpool.
1873. ‡Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1867. STORRAR, JOHN, M.D. Heathview, Hampstead, London, N.W.
1859. §Story, James. 17 Bryanston-square, London, W.

Year of Election.

1874. §Stott, William. Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Lieut.-General RICHARD, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S. Stowey House, Clapham Common, London, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
*Strickland, Charles. Loughglyn House, Castlerea, Ireland.
Strickland, William. French Park, Roscommon, Ireland.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1876. *Struthers, John, M.D., Professor of Anatomy in the University of Aberdeen.
1878 §Strype, W. G., C.E. Wicklow.
1876. *Stuart, Charles Maddock. Sudbury Hill, Harrow.
1872. *Stuart, Rev. Edward A. 22 Bedford-street, Norwich.
1864. ‡Style, Sir Charles, Bart. 102 New Sydney-place, Bath.
1873. §Style, George, M.A. Giggleswick School, Yorkshire.
1857. ‡SULLIVAN, WILLIAM K., Ph.D., M.R.I.A. Queen's College, Cork.
1873. ‡Sutcliffe, J. W. Sprink Bank, Bradford, Yorkshire.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
1862. *SUTHERLAND, GEORGE GRANVILLE WILLIAM, Duke of, K.G., F.R.S., F.R.G.S. Stafford House, London, S.W.
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1876. ‡Swan, David, jun. Braeside, Maryhill, Glasgow.
1861. *Swan, Patrick Don S. Kirkcaldy, N.B.
1862. *SWAN, WILLIAM, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews. Ardchapel, by Helensburgh, N.B.
1862. *Swann, Rev. S. Kirke, F.R.A.S. Forest Hill Lodge, Warsop, Mansfield, Nottinghamshire.
Sweetman, Walter, M.A., M.R.I.A. 4 Mountjoy-square North, Dublin.
1870. *Swinburne, Sir John, Bart. Capheaton, Newcastle-on-Tyne.
1863. ‡Swindell, J. S. E. Summerhill, Kingswinford, Dudley.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1873. §Sykes, Benjamin Clifford, M.D. Cleckheaton.
1847. ‡Sykes, H. P. 47 Albion-street, Hyde Park, London, W.
1862. ‡Sykes, Thomas. Cleckheaton, near Leeds.
1847. ‡Sykes, Captain W. H. F. 47 Albion-street, Hyde Park, London, W.
SYLVESTER, JAMES JOSEPH, M.A., LL.D., F.R.S. Athenæum Club, London, S.W.
1870. §SYMES, RICHARD GLASCOTT, A.B., F.G.S. Geological Survey of Ireland, 14 Hume-street, Dublin.
1856. *Symonds, Frederick, M.A., F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1860. ‡SYMONDS, Rev. W. S., M.A., F.G.S. Pendock Rectory, Worcestershire.
1859. §SYMONS, G. J., F.R.S., Sec. M.S. 62 Camden-square, London, N.W.
1855. *SYMONS, WILLIAM, F.C.S. 26 Joy-street, Barnstaple.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.
1872. ‡Synge, Major-General Millington, R.E., F.S.A., F.R.G.S. United Service Club, Pall Mall, London, S.W.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.

Year of
Election.
1877. *TAIT, LAWSON, F.R.C.S. 7 Great Charles-street, Birmingham.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡Tait, P. M., F.R.G.S. Oriental Club, Hanover-square, London, W.
§Talbot, William Hawkshead. Hartwood Hall, Chorley, Lancashire.
1874. §Talmage, C. G. Leyton Observatory, Essex, E.
1866. ‡Tarbottom, Marrott Ogle, M.I.C.E., F.G.S. Newstead-grove, Nottingham.
1878. §Tarpey, Hugh. Dublin.
1861. *Tarratt, Henry W. Mountfield, Grove Hill, Tunbridge Wells.
1856. ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1857. *Tate, Alexander. 2 Queen's-elms, Belfast.
1863. ‡Tate, John. Alnmouth, near Alnwick, Northumberland.
1870. ‡Tate, Norman A. 7 Nivell-chambers, Fazackerley-street, Liverpool.
1858. *Tatham, George. Springfield Mount, Leeds.
1876.§§Tatlock, Robert R. 26 Burnbank-gardens, Glasgow.
1864. *TAWNEY, EDWARD B., F.G.S. Woodwardian Museum, Cambridge.
1871. ‡Tayler, William, F.S.A., F.S.S. 28 Park-street, Grosvenor-square, London, W.
1878. *Taylor, A. Claude. Clinton House, The Park, Nottingham.
1874. ‡Taylor, Alexander O'Driscoll. 3 Upper-crescent, Belfast.
1867. ‡Taylor, Rev Andrew. Dundee.
Taylor, Frederick. Laurel Cottage, Rainhill, near Prescot, Lancashire.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
*TAYLOR, JOHN, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1861. *Taylor, John, jun. 6 Queen-street-place, Upper Thames-street, London, E.C.
1873. ‡TAYLOR, JOHN ELLOR, F.L.S., F.G.S. The Mount, Ipswich.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
*TAYLOR, RICHARD, F.G.S 6 Queen-street-place, Upper Thames-street, London, E.C.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1878. §Taylor, Robert, J.P., LL.D. Corballis, Drogheda.
1870.§§Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
*Taylor, William Edward. Millfield House, Enfield, near Accrington.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
1869. ‡Teesdale, C. S. M. Whyke House, Chichester.
1876. ‡Temperley, Ernest. Queen's College, Cambridge.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
*TENNANT, JAMES, F.G.S., F.R.G.S., Professor of Mineralogy in King's College. 149 Strand, London, W.C.
1857. ‡Tennison, Edward King. Kildare-street Club House, Dublin.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., M.A., B.Sc., F.L.S. 10 Gloucester-road, Kew, W.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1875. *THOMAS, CHRISTOPHER JAMES. Drayton Lodge, Redland, Bristol.
Thomas, George. Brislington, Bristol.
1875. §Thomas, Herbert. 2 Great George-street, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.

Year of Election.

1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1875.§§Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1863. ‡Thompson, Rev. Francis. St. Giles's, Durham.
1858. *Thompson, Frederick. South-parade, Wakefield.
1859.§§Thompson, George, jun. Pidsmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
Thompson, Henry Stafford. Fairfield, near York.
1861. *Thompson, Joseph. Woodlands, Fulshaw, near Manchester.
1864. ‡THOMPSON, Rev. JOSEPH HESSELGRAVE, B.A. Cradley, near Brierley Hill.
Thompson, Leonard. Sheriff-Hutton Park, Yorkshire.
1873. ‡Thompson, M. W. Guiseley, Yorkshire.
1876. *Thompson, Richard. Park-street, The Mount, York.
1874. §Thompson, Robert. Walton, Fortwilliam Park, Belfast.
1876. §THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.A.S., Professor of Physics in University College, Bristol. 8 Carlton-place, Clifton, Bristol.
1878. §Thompson, T. D. Clare Hall, Raheny, Co. Dublin.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1855. ‡THOMSON, ALLEN, M.D., LL.D., F.R.S. L. & E. 66 Palace Gardens-terrace, Kensington, London, W.
1850. ‡THOMSON, Sir CHARLES WYVILLE. LL.D., F.R.S. L. & E., F.G.S., Regius Professor of Natural History in the University of Edinburgh. 20 Palmerston-place, Edinburgh.
1852. ‡*Thomson, Gordon A. Bedeque House, Belfast.*
Thomson, Guy. Oxford.
1850. *THOMSON, Professor JAMES, M.A., LL.D., C.E., F.R.S. L. & E. Oakfield House, University Avenue, Glasgow.
1855. ‡*Thompson, James. 82 West Nile-street, Glasgow.*
1868. §THOMSON, JAMES, F.G.S. 3 Abbotsford-place, Glasgow.
*Thomson, James Gibson. 14 York-place, Edinburgh.
1876.§§Thomson, James R. Dalmuir House, Dalmuir, Glasgow.
1874. ‡Thompson, John. Harbour Office, Belfast.
1871. *Thomson, John Millar, F.C.S. King's College, London, W.C.
1871. ‡Thomson, Robert, LL.B. 12 Rutland-square, Edinburgh.
1865. ‡Thomson, R. W., C.E., F.R.S.E. 3 Moray-place, Edinburgh.
1847. *THOMSON, Sir WILLIAM, M.A., LL.D., D.C.L., F.R.S. L. & E., Professor of Natural Philosophy in the University of Glasgow, The University, Glasgow.
1877. *Thomson, Lady. The University, Glasgow.
1874. §Thomson, William, F.R.S.E., F.C.S. Royal Institution, Manchester.
1876. ‡Thomson, William. 6 Mansfield-place, Edinburgh.
1871.§§Thomson, William Burnes, F.R.S.E. 1 Ramsay-gardens, Edinburgh.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thornburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
1866. ‡Thornton, James. Edwalton, Nottingham.
*Thornton, Samuel, J.P. Oakfield, Moseley, near Birmingham.
1867. ‡Thornton, Thomas. Dundee.
1845. §Thorp, Dr. Disney. Suffolk Laun, Cheltenham.
1871. §Thorp, Henry. Briarleigh, Sale, near Manchester.
1864. *THORP, WILLIAM, B.Sc., F.C.S. 39 Sandringham-road, Kingsland, London, E.
1871.§§THORPE, T. E., Ph.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in Yorkshire College, Leeds.

Year of
Election.
1868. ‡Thuillier, Colonel, R.A., C.S.I., F.R.S., Surveyor-General of India. 46 Park-street, Calcutta.
1870. ‡Tichborne, Charles R. C., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *TIDDEMAN, R. H., M.A.. F.G.S. 28 Jermyn-street, London, S.W.
1874. ‡Tilden, William A., D.Sc., F.C.S. Clifton College, Bristol.
1873. ‡Tilghman, B. C. Philadelphia, United States.
1865.§§Timmins, Samuel, J.P., F.S.A. Elvetham-road, Edgbaston, Birmingham.
Tinker, Ebenezer. Mealhill, near Huddersfield.
*TINNE, JOHN A., F.R.G.S. Briarley, Aigburth, Liverpool.
1876.§§Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.
1861. *TODHUNTER, ISAAC, M.A., F.R.S., Principal Mathematical Lecturer at St. John's College, Cambridge. Brookside, Cambridge.
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1856. ‡Tomes, Robert Fisher. Welford, Stratford-on-Avon.
1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 3 Ridgmount-terrace. Highgate, London, N.
1863. ‡Tone, John F. Jesmond-villas, Newcastle-on-Tyne.
1865. §Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865.§§Tonks, William Henry. The Rookery, Sutton Coldfield.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1861. *Topham, John, A.I.C.E. High Elms, 265 Mare-street, Hackney, London, E.
1872. *TOPLEY, WILLIAM, F.G.S., A.I.C.E. Geological Survey Office, Jermyn-street, London, S.W.
1875. §Torr, Charles Hawley. Harrowby House, Park-row, Nottingham.
1863. ‡Torrens, Colonel Sir R. R., K.C.M.G. 2 Gloucester-place, Hyde Park, London, W.
1859. ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.
Towgood, Edward. St. Neot's, Huntingdonshire.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. ‡Townsend, Charles. Avenue House, Cotham Park, Bristol.
1857. *TOWNSEND, Rev. RICHARD, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1854. ‡TOWSON, JOHN THOMAS, F.R.G.S. 47 Upper Parliament-street, Liverpool; and Local Marine Board, Liverpool.
1877. §Tozer, Henry. Ashburton.
1876. *Trail, J. W. H., M.A., M.B., F.L.S. King's College, Old Aberdeen.
1870. ‡TRAILL, WILLIAM A., M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1875.§§Trapnell, Caleb. Severnleigh, Stoke Bishop.
1868. ‡TRAQUAIR, RAMSAY H., M.D., Professor of Zoology. Museum of Science and Art, Edinburgh.
1835. Travers, Robert, M.B. Williamstown, Blackrock, Co. Dublin.
1865. ‡Travers, William, F.R.C.S. 1 Bath-place, Kensington, London, W.
Tregelles, Nathaniel. Liskeard, Cornwall.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1869. ‡Trehane, John, jun. Bedford-circus, Exeter.
1870. ‡Trench, Dr. Municipal Offices, Dale-street, Liverpool.
Trench, F. A. Newlands House, Clondalkin, Ireland.
*TREVELYAN, ARTHUR, J.P. Tyneholm, Pencaitland, N.B.

Year of Election.

TREVELYAN, Sir WALTER CALVERLEY, Bart., M.A., F.R.S.E., F.G.S., F.S.A., F.R.G.S. Athenæum Club, London, S.W.; Wallington, Northumberland; and Nettlecombe, Somerset.
1871. ‡TRIBE, ALFRED, F.C.S. 14 Denbigh-road, Bayswater, London, W.
1871. ‡TRIMEN, ROWLAND, F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1877. §§TRIMEN, HENRY, M.B., F.L.S. British Museum, London, W.C.
1860. §TRISTRAM, Rev. HENRY BAKER, M.A., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1864. ‡*Truell, Robert. Ballyhenry, Ashford, Co. Wicklow.*
1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. 10 Baldwin-street, Bristol.
Tuke, James H. Bank, Hitchen.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1867. ‡Tulloch, The Very Rev. Principal, D.D. St. Andrew's, Fifeshire.
1854. ‡TURNBULL, JAMES, M.D. 86 Rodney-street, Liverpool.
1855. §Turnbull, John. 37 West George-street, Glasgow.
1856. ‡Turnbull, Rev. J. C. 8 Bays-hill-villas, Cheltenham.
1871. §§Turnbull, William, F.R.S.E. 14 Lansdowne-crescent, Edinburgh.
1873. *Turner, George. Horton Grange, Bradford, Yorkshire.
Turner, Thomas, M.D. 31 Curzon-street, Mayfair, London, W.
1875. ‡Turner, Thomas, F.S.S. Ashley House, Kingsdown, Bristol.
1863. *TURNER, WILLIAM, M.B., F.R.S. L. & E., Professor of Anatomy in the University of Edinburgh. 16 Eton-terrace, Edinburgh.
1842. Twamley, Charles, F.G.S. Ryton-on-Dunsmore, Coventry.
1847. ‡TWISS, Sir TRAVERS, Q.C., D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.
1865. §§TYLOR, EDWARD BURNETT, F.R.S. Linden, Wellington, Somerset.
1858. *TYNDALL, JOHN, D.C.L., LL.D., Ph.D., F.R.S., F.G.S., Professor of Natural Philosophy in the Royal Institution. Royal Institution, Albemarle-street, London, W.
1861. *Tysoe, John. 28 Seedley-road, Pendleton, near Manchester.

1876. *UNWIN, W. C., A.I.C.E., Professor of Hydraulic Engineering. Cooper's Hill, Middlesex.
1872. ‡Upward, Alfred. 11 Great Queen-street, Westminster, London, S.W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.

*Vance, Rev. Robert. 24 Blackhall-street, Dublin.
1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1854. ‡Varley, Cromwell F., F.R.S. Fleetwood House, Beckenham, Kent.
1868. §§Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, London, N.
1865. *VARLEY, S. ALFRED. Hatfield, Herts.
1870. ‡Varley, Mrs. S. A. Hatfield, Herts.
1869. ‡Varwell, P. Alphington-street, Exeter.
1875. §§Vaughan, Miss. Burlton Hall, Shrewsbury.
1849. *Vaux, Frederick. Central Telegraph Office, Adelaide, South Australia.

Year of Election

1873. *VERNEY, Captain EDMUND H., R.N., F.R.G.S. Rhianva, Bangor, North Wales.

Verney, Sir Harry. Bart. Lower Claydon, Buckinghamshire.

1866. ‡Vernon, Rev. E. H. Harcourt. Cotgrave Rectory, near Nottingham.

Vernon, George John, Lord. 32 Curzon-street, London, W.; and Sudbury Hall, Derbyshire.

1854. *VERNON, GEORGE V., F.R.A.S. 1 Osborne-place, Old Trafford, Manchester.

1864. *VICARY, WILLIAM, F.G.S. The Priory, Colleton-crescent, Exeter.

1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.

1875. ‡Vines, David, F.R.A.S. Observatory House, Somerset-street, Kingsdown, Bristol.

1856. ‡VIVIAN, EDWARD, M.A. Woodfield, Torquay.

*VIVIAN, H. HUSSEY, M.P., F.G.S. Park Werne, Swansea; and 27 Belgrave-square, London, S.W.

1856.§§VOELCKER, J. CH. AUGUSTUS, Ph.D., F.R.S., F.C.S., Professor of Chemistry to the Royal Agricultural Society of England. 39 Argyll-road, Kensington, London, W.

1875. ‡Volckman, Mrs. E. G. 43 Victoria-road, Kensington, London, W.

1875. ‡Volckman, William. 43 Victoria-road, Kensington, London, W.

‡Vose, Dr., James. Gambier-terrace, Liverpool.

1875. ‡*Wace, Rev. A. St. Paul's, Maidstone, Kent.*

1860.§§Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.

1859. ‡Waddington, John. New Dock Works, Leeds.

1870. §WAKE, CHARLES STANILAND. 70 Wright-street, Hull.

1855. *Waldegrave, The Hon. Granville. 26 Portland-place, London, W.

1873. ‡Wales, James. 4 Mount Royd, Manningham, Bradford, Yorkshire.

1869. *Walford, Cornelius. 86 Belsize Park-gardens, London, N.W.

1849. §WALKER, CHARLES V., F.R.S., F.R.A.S. Fernside, Reigate Hill, Reigate.

Walker, Sir Edward S. Berry Hill, Mansfield.

Walker, Frederick John. The Priory, Bathwick, Bath.

1866. ‡Walker, H. Westwood, Newport, by Dundee.

1855. ‡Walker, John. 1 Exchange-court, Glasgow.

1842. *Walker, John. Thorncliffe, Kenilworth-road, Leamington.

1866. *WALKER, J. F., M.A., F.C.P.S., F.C.S., F.G.S., F.L.S. 16 Gillygate, York.

1867. *Walker, Peter G. 2 Airlie-place, Dundee.

1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.

1869. *Walker, Thomas F. W., M.A., F.G.S., F.R.G.S. 3 Circus, Bath.

Walker, William. 47 Northumberland-street, Edinburgh.

1869. ‡*Walkey, J. E. C. High-street, Exeter.*

1863. ‡WALLACE, ALFRED RUSSEL, F.R.G.S., F.L.S. Waldron Edge, Duppas Hill, Croydon.

1859. ‡WALLACE, WILLIAM, Ph.D., F.C.S. Chemical Laboratory, 138 Bath-street, Glasgow.

1857. ‡Waller, Edward. Lisenderry, Aughnacloy, Ireland.

1862. ‡WALLICH, GEORGE CHARLES, M.D., F.R.G.S., F.L.S. Terrace House, St. George's-terrace, Herne Bay.

1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., M.P., F.R.S. Ealing, London, W.

1857. ‡Walsh, Albert Jasper, F.R.C.S.I. 89 Harcourt-street, Dublin.

Walsh, John (Prussian Consul). Dundrum Castle, Co. Dublin.

1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.

Walton, Thomas Todd. Mortimer House, Clifton, Bristol.

Year of Election.

1863. ‡Wanklyn, James Alfred. 117 Charlotte-street, Fitzroy-square, London, W.
1872. ‡Warburton, Benjamin. Leicester.
1874. §Ward, F. D. Fernleigh, Botanic-road, Belfast.
1874. §Ward, John, F.R.G.S. Lenox Vale, Belfast.
1857. ‡Ward, John S. Prospect-hill, Lisburn, Ireland.
Ward, Rev. Richard, M.A. 12 Eaton-place, London, S.W.
1863. ‡Ward, Robert. Dean-street, Newcastle-on-Tyne.
*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
1867. ‡Warden, Alexander J. Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1865. ‡Waring, Edward John, M.D., F.L.S. 49 Clifton-gardens, Maida Vale, London, W.
1878. §Warington, Robert. Harpenden, St. Alban's, Herts.
1864. *Warner, Edward. 49 Grosvenor-place, London, S.W.
1872. *Warner, Thomas. 47 Sussex-square, Brighton.
1856. ‡Warner, Thomas H. Lee. Tiberton Court, Hereford.
1875. ‡Warren, Algernon. Naseby House, Pembroke-road, Clifton, Bristol.
1865. *Warren, Edward P. 13 Old-square, Birmingham.
Warwick, William Atkinson. Wyddrington House, Cheltenham.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
1876. ‡Waterhouse, A. Willenhall House, Barnet, Herts.
*WATERHOUSE, JOHN, F.R.S., F.G.S., F.R.A.S. Wellhead, Halifax, Yorkshire.
1875. *Waterhouse, Captain J. Surveyor-General's Office, Calcutta. (Care of Messrs. Trubner & Co., Ludgate-hill, London, E.C.
1854. ‡Waterhouse, Nicholas. 5 Rake-lane, Liverpool.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1875. §Waters, Arthur W., F.G.S., F.L.S. Woodbrook, Alderley Edge, near Manchester.
1875. ‡Watherston, Alexander Law, M.A., F.R.A.S. Bowdon, Cheshire.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1855. ‡Watson, Ebenezer. 16 Abercromby-place, Glasgow.
1867. ‡Watson, Frederick Edwin. Thickthorne House, Cringleford, Norwich.
*WATSON, HENRY HOUGH, F.C.S. 227 The Folds, Bolton-le-Moors.
WATSON, HEWETT COTTRELL. Thames Ditton, Surrey.
1873. *Watson, Sir James. Milton-Lockhart, Carluke, N.B.
1859. ‡WATSON, JOHN FORBES, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham-grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. ‡Watson, Thomas Donald. 41 Cross-street, Finsbury, London, E.C.
1869. ‡Watt, Robert B. E., C.E., F.R.G.S. Ashley-avenue, Belfast.
1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.
1875. *WATTS, JOHN, B.A., D.Sc. 57 Baker-street, Portman-square, London, W.
1846. §Watts, John King, F.R.G.S. Market-place, St. Ives, Hunts.
1870. §Watts, William. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
1858. ‡Waud, Major E. Manston Hall, near Leeds.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1859. ‡Waugh, Edwin. Sager-street, Manchester.

Year of Election.

1859. *WAVENEY, The Right Hon. Loid, F.R.S. 7 Audley-squaie, London, W.

*WAY, J. THOMAS, F.C.S. 9 Russell-road, Kensington, London, S.W.

1869. ‡Way, Samuel James. Adelaide, South Australia.

1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.

*WEBB, Rev. THOMAS WILLIAM, M.A., F.R.A.S. Hardwick Vicarage, Hay, South Wales.

1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.

1859. ‡Webster, John. 42 King-street, Aberdeen.

1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.

1845. ‡*Wedgewood, Hensleigh.* 17 *Cumberland-terrace, Regent's Paık, London, N.W.*

1854. ‡Weightman, William Henry. Farn Lea, Seaforth, Liverpool.

1865. ‡Welch, Christopher, M A. University Club, Pall Mall East, London, S.W.

1867. §WELDON, WALTER, F.R.S.E. Rede Hall, Burstow, Surrey.

1878. §Weldon, Mrs. Walter. Rede Hall, Burstow, Surrey.

1876. §Weldon, W. F. R. Abbey Lodge, Merton, Surrey.

1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.

Wentworth, Frederıck W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.

1864. *Were, Anthony Berwick. Whitehaven, Cumberland.

1853. ‡West, Alfred. Holderness-road, Hull.

1870. ‡West, Captain E. W. Bombay.

1853. ‡West, Leonard. Summergangs Cottage, Hull.

1853. ‡West, Stephen. Hessle Grange, near Hull.

1851. *WESTERN, Sir T. B., Bart. Felix Hall, Kelvedon, Essex.

1870. §Westgarth, William. 10 Bolton-gardens, South Kensington, London, W.

1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.

Westhead, John. Manchester.

1842. *Westhead, Joshua Proctor Brown. Lea Castle, near Kidderminster.

1857. *Westley, William. 24 Regent-street, London, S.W.

1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.

1860. ‡Weston, James Woods. Belmont House, Pendleton, Manchester.

1875. *Weston, Joseph D. Dorset House, Clifton Down, Bristol.

1864. ‡WESTROPP, W. H. S., M.R.I.A Lisdoonvarna, Co. Clare.

1860. ‡WESTWOOD, John O., M.A., F.L S., Professor of Zoology in the University of Oxford Oxford.

1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.

1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N W.

1847. ‡Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London, N.

1878. *Wheeler, W. H., C.E. Churchyard, Boston, Lincolnshire.

1873. ‡Whipple, George Matthew, B.Sc., F.R.A.S. Kew Observatory, Richmond, Surrey.

1874. §Whitaker, Henry, M.D. 11 Clarence-place, Belfast.

1859. *WHITAKER, WILLIAM, B.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.

1876. ‡White, Angus. Easdale, Argyleshire.

1864. ‡White, Edmund. Victoria Villa, Batheaston, Bath.

1837. ‡WHITE, JAMES, F.G.S. 58 Gresham House, Old Broad-stıeet, London, E.C.

Year of Election.

1876. *White, James. Overtoun, Dumbarton.
1873. §White, John. Medina Docks, Cowes, Isle of Wight.
White, John. 80 Wilson-street, Glasgow.
1859. ‡WHITE, JOHN FORBES. 16 Bon Accord-square, Aberdeen.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. ‡White, Laban. Blanford, Dorset.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 365 Euston-road, London, N.W.
1861. ‡Whitehead, James, M.D. 87 Mosley-street, Manchester.
1858. ‡Whitehead, J. H. Southsyde, Saddleworth.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod. Belmont, Rawtenstall, Manchester.
1855. **Whitehouse, Wildeman, W. O. 12 Thurlow-road, Hampstead, London, N.W.*
Whitehouse, William. 10 Queen's-street, Rhyl.
1871. ‡Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.
1866. ‡Whitfield, Samuel. Golden Hillock, Small Heath, Birmingham.
1874. ‡Whitford, William. 5 Claremont-street, Belfast.
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Charles Thomas, M.A., F.R.A.S. Bedlington, Morpeth.
1870. §Whittem, James Sibley. Walgrave, near Coventry.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. 94 Baggot-street, Dublin.
1874. *Whitwell, Mark. Redland House, Bristol.
1863. *Whitwell, Thomas. Thornaby Iron Works, Stockton-on-Tees.
*WHITWORTH, Sir JOSEPH, Bart., LL.D., D.C.L., F.R.S. The Firs, Manchester; and Stancliffe Hall, Derbyshire.
1870. ‡WHITWORTH, Rev. W. ALLEN, M.A. 185 Islington, Liverpool.
1878. §Wigham, John R. Albany House, Monkstown, Dublin.
1865. ‡Wiggin, Henry. Metchley Grange, Harbourne, Birmingham.
1855. ‡Wilkie, John. Westburn, Helensburgh, N.B.
1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.
1859. §Wilkinson, Robert. Lincoln Lodge, Totteridge, Hertfordshire.
1872. §Wilkinson, William. 168 North-street, Brighton.
1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay.
*Willert, Alderman Paul Ferdinand. Town Hall, Manchester.
1859. ‡Willet, John, C.E. 35 Albyn-place, Aberdeen.
1872. ‡WILLETT, HENRY, F.G.S. Arnold House, Brighton.
1870. ‡*William, G. F. Copely Mount, Springfield, Liverpool.*
WILLIAMS, CHARLES JAMES, B., M.D., F.R.S. 47 Upper Brook-street, Grosvenor-square, London, W.
1861. *Williams, Charles Theodore, M.A., M.B. 47 Upper Brook-street, Grosvenor-square, London, W.
1864. *WILLIAMS, Sir FREDERICK, M., Bart., M.P., F.G.S. Goonvrea, Perranarworthal, Cornwall.
1861. *Williams, Harry Samuel, M.A. 28 John-street, Bedford-row, London, W.C.
1875. *Williams, Herbert A., B.A. 91 Pembroke-road, Clifton, Bristol.
1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1870. §WILLIAMS, JOHN, F.C.S. 14 Buckingham-street, London, W.C.
1875. *Williams, M. B. North Hill, Swansea.
Williams, Robert, M.A. Bridehead, Dorset.
1869. ‡WILLIAMS, Rev. STEPHEN. Stonyhurst College, Whalley, Blackburn.
1877. *Williams, W. Carleton, F.C.S. Owens College, Manchester.
1865. ‡Williams, W. M. Belmont-road, Twickenham, near London.

Year of
Election.

1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., For. Sec. R.S., F.C.S., Corresponding Member of the French Academy, Professor of Chemistry, and of Practical Chemistry, University College, London. (GENERAL TREASURER.) University College, London, W.C.
1857. ‡Williamson, Benjamin, M.A. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
1876. §§Williamson, Stephen. 19 James-street, Liverpool.
WILLIAMSON, WILLIAM C., F.R.S., Professor of Natural History in Owens College, Manchester. 4 Egerton-road, Fallowfield, Manchester.
1865. *Willmott, Henry. Hatherley Lawn, Cheltenham.
1857. ‡*Willock, Rev. W. N., D.D. Cleenish, Enniskillen, Ireland.*
1859. *Wills, Alfred, Q.C. 12 King's Bench-walk, Inner Temple, E.C.
1865. ‡Wills, Arthur W. Edgbaston, Birmingham.
1874. §WILLS, THOMAS, F.C.S. Royal Naval College, Greenwich, S.E.
WILLS, W. R. Edgbaston, Birmingham.
1878. §Wilson, Alexander, S., M.A., B.Sc. 124 Bothwell-street, Glasgow.
1859. §Wilson, Alexander Stephen, C.E. North Kinmundy, Summerhill, by Aberdeen.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1674. §WILSON, Major C. W., C B., R.E., F.R.S., F.R.G.S , Director of the Topographical and Statistical Department of the War Office. Ordnance Survey Office, Dublin.
1850. ‡Wilson, Dr. Daniel. Toronto, Upper Canada.
1876. §§Wilson, David. 124 Bothwell-street, Glasgow.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 73 Newman-street, Oxford-street, London, W.
Wilson, George. 40 Ardwick-green, Manchester.
1861. ‡Wilson, George Daniel. 24 Ardwick-green, Manchester.
1875. §Wilson, George Fergusson, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron-hill, Hawick, N.B.
1855. ‡Wilson, Hugh. 75 Glasford-street, Glasgow.
1857. ‡Wilson, James Moncrieff. Queen Insurance Company, Liverpool.
1865. ‡WILSON, JAMES M., M.A. Hillmorton-road, Rugby.
1858. *Wilson, John. Seacroft Hall, near Leeds.
WILSON, JOHN, F.G.S., F.R.S.E., Professor of Agriculture in the University of Edinburgh. The University, Edinburgh.
1876. ‡Wilson, J. G., M.D., F.R.S.E. 9 Woodside-crescent, Glasgow.
1876. §Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1863. *Wilson, Thomas. Shotley Hall, Shotley Bridge, Northumberland.
1861. ‡Wilson, Thomas Bright. 24 Ardwick-green, Manchester.
1867. ‡Wilson, Rev. William. Free St. Paul's, Dundee.
1871. *Wilson, William E. Daramona House, Rathowen, Ireland.
1870. ‡Wilson, William Henry. 31 Grove-park, Liverpool.
1861. *WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S. 25 Granville-park, Lewisham, London, S.E.
1877. §§Windeatt, T. W. Dart View, Totnes.
1866. *Windley, W. Mapperley Plains, Nottingham.
*Winsor, F. A. 60 Lincoln's-Inn-fields, London, W.C.
1868. ‡Winter, C. J. W. 22 Bethel-street, Norwich.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.

Year of
Election.
1863. *Wood, Collingwood L. Freeland, Bridge of Earn, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
*Wood, George B., M.D. 1117 Arch-street, Philadelphia, United States.
1870. *Wood, George S. 20 Lord-street, Liverpool.
1875. *Wood, George William Rayner. Singleton, Manchester.
1856. *WOOD, Rev. H. H., M.A., F.G.S. Holwell Rectory, Sherborne, Dorset.
1878. §Wood, H. Trueman, B.A. Society of Arts, John-street, Adelphi, London, W.C.
1864. †Wood, Richard, M.D. Driffield, Yorkshire.
1861. §Wood, Samuel, F.S.A. St. Mary's Court, Shrewsbury.
1871. ‡Wood, Provost, T. Barleyfield, Portobello, Edinburgh.
1850. ‡Wood, Rev. Walter. Elie, Fife.
Wood, William. Edge-lane, Liverpool.
1865. *Wood, William, M.D. 99 Harley-street, London, W.
1861. ‡Wood, William Rayner. Singleton Lodge, near Manchester.
1872. §Wood, William Robert. Carlisle House, Brighton.
*Wood, Rev. William Spicer, M.A., D.D. Higham, Rochester.
1863. *WOODALL, Major JOHN WOODALL, M.A., F.G.S. St. Nicholas House, Scarborough.
1870. ‡Woodburn, Thomas. Rock Ferry, Liverpool.
1850. *Woodd, Charles H. L., F.G.S. Roslyn House, Hampstead, London, N.W.
1865. ‡Woodhill, J. C. Pakenham House, Charlotte-road, Edgbaston, Birmingham.
1871. ‡Woodiwis, James. 51 Back George-street, Manchester.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
1869. ‡Woodman, William Robert, M.D. Ford House, Exeter.
*WOODS, EDWARD, C.E. 3 Great George-street, Westminster, London, S.W.
WOODS, SAMUEL. 5 Austin Friars, Old Broad-street, London, E.C.
*WOODWARD, C. J., B.Sc. 76 Francis-road, Edgbaston, Birmingham.
1866. ‡WOODWARD, HENRY, F.R.S., F.G.S. British Museum, London, W.C.
1870. ‡Woodward, Horace B., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1877.§§Woollcombe, Robert W. 14 St. Jean d'Acre-terrace, Plymouth.
1856. ‡Woolley, Thomas Smith, jun. South Collingham, Newark.
1872. ‡Woolmer, Shirley. 6 Park-crescent, Brighton.
Worcester, The Right Rev. Henry Philpott, D.D., Lord Bishop of Worcester.
1874. ‡Workman, Charles. Ceara, Windsor, Belfast.
1878. §Wormell, Richard, M.A., D.Sc. 165 Loughborough-road, London, S.W.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Old Meeting Parsonage, Mansfield.
Worthington, Archibald. Whitchurch, Salop.
Worthington, James. Sale Hall, Ashton-on-Mersey.
Worthington, William. Brockhurst Hall, Northwich, Cheshire.
1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.
1871. §WRIGHT, C. R. A., D.Sc., F.C.S., Lecturer on Chemistry in St. Mary's Hospital Medical School, Paddington, London, W.
1861. *Wright, E. Abbot. Castle Park, Frodsham, Cheshire.

Year of Election.

1857. ‡WRIGHT, E. PERCEVAL, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany, and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1866. ‡Wright, G. H. Heanor Hall, near Derby.
1876. ‡Wright, James 114 John-street, Glasgow.
1874. ‡Wright, Joseph. Cliftonville, Belfast.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
*Wright, Robert Francis. Hinton Blewett, Temple-Cloud, near Bristol.
1855. ‡WRIGHT, THOMAS, M.D., F.R.S.E., F.G.S., St. Margaret's-terrace, Cheltenham.
Wright, T. G., M.D. Milnes House, Wakefield.
1876. ‡Wright, William. 101 Glassford-street, Glasgow.
1871. ‡Wrightson, Thomas. Norton Hall, Stockton-on-Tees.
1867. ‡WUNSCH, EDWARD ALFRED. 146 West George-street, Glasgow.
Wyld, James, F.R.G.S. Charing Cross, London, W.C.
1863. *Wyley, Andrew. 21 Barker-street, Handsworth, Birmingham.
1867. ‡Wylie, Andrew. Prinlaws, Fifeshire.
1871. §Wynn, Mrs. Williams. Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S., of the Geological Survey of India. Bombay.

1875. §§Yabbicom, Thomas Henry, C.E. 37 White Ladies-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1865. ‡Yates, Edwin. Stonebury, Edgbaston, Birmingham.
Yates, James. Carr House, Rotherham, Yorkshire.
1867. ‡Yeaman, James. Dundee.
1855. ‡Yeats, John, LL.D., F.R.G.S. Clayton-place, Peckham, London, S.E.
1877. §Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1870. ‡YOUNG, JAMES, F.R.S. L. & E., F.C.S. Kelly, Wemyss Bay, by Greenock.
Young, John. Taunton, Somersetshire.
1876. ‡YOUNG JOHN, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
1876. *Young, John, F.C.S. Kelly, Wemyss Bay, by Greenock.
Younge, Robert, F.L.S. Greystones, near Sheffield.
1868. ‡Youngs, John. Richmond Hill, Norwich.
1876. ‡Yuille, Andrew. 7 Sardinia-terrace, Hillhead, Glasgow.
1871. ‡YULE, Colonel HENRY, C.B. East India United Service Club, St. James's-square, London, S.W.

CORRESPONDING MEMBERS.

Year of Election.

1871. HIS IMPERIAL MAJESTY THE EMPEROR OF THE BRAZILS.
1868. M. D'Avesac, Mem. de l'Institut de France. 42 Rue du Bac, Paris.
1866. Captain I. Belavenetz, R.I.N., F.R.I.G.S., M.S.C.M.A., Superintendent of the Compass Observatory, Cronstadt, Russia.
1870. Professor Van Beneden, LL.D. Louvain, Belgium.
1872. Ch. Bergeron, C.E. 26 Rue des Penthievre, Paris.
1861. Dr. Bergsma, Director of the Magnetic Survey of the Indian Archipelago. Utrecht, Holland.
1874. M. A. Niaudet Breguet. 39 Quai de l'Horloge, Paris.
1868. Professor Broca. Paris.
1864. Dr. H. D. Buys-Ballot, Superintendent of the Royal Meteorological Institute of the Netherlands. Utrecht, Holland.
1861. Dr. Carus. Leipzig.
1864. M. Des Cloizeaux. Paris.
1871. Professor Dr. Colding. Copenhagen.
1873. Signor Guido Cora. 17 Via Providenza, Turin.
1870. J. M. Crafts, M.D.
1855. Dr. Ferdinand Cohn. Breslau, Prussia.
1876. Professor Luigi Cremona. The University, Rome.
1872. Professor M. Croullebois. 18 Rue Sorbonne, Paris.
1874. M. Ch. D'Almeida. 31 Rue Bonaparte, Paris.
1866. Dr. Geheimrath von Dechen. Bonn.
1862. Wilhelm Delffs, Professor of Chemistry in the University of Heildelberg.
1872. Professor G. Devalque. Liége, Belgium.
1870. Dr. Anton Dohrn. Naples.
1845. Heinrich Dove, Professor of Natural Philosophy in the University of Berlin.
Professor Dumas. Paris.
1876. Professor Alberto Eccher. Florence.
1848. Professor Esmark. Christiania.
1861. Professor A. Favre. Geneva.
1874. Dr. W. Feddersen. Leipzig.
1872. W. de Fonvielle. Rue des Abbesses, Paris.
1856. Professor E. Frémy. Paris.
1842. M. Frisiani.
1866. Dr. Gaudry, Pres. Geol. Soc. of France. Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1872. Professor Paul Gervais. Museum de Paris.
1870. Governor Gilpin. Colorado, United States.
1876. Dr. Benjamin A. Gould, Director of the Argentine National Observatory.
1852. Professor Asa Gray. Cambridge, United States.
1866. Professor Edward Grube, Ph.D. Breslau.
1871. Dr. Paul Gussfeldt, of the University of Bonn. 33 Meckenheimerstrasse, Bonn, Prussia.
1876. Professor Ernst Haeckel. Jena.

Year of Election.

1862. Dr. D. Bierens de Haan, Member of the Royal Academy of Sciences, Amsterdam. Lieden, Holland.
1872. Professor James Hall. Albany, State of New York.
1864. M. Hébert, Professor of Geology in the Sorbonne, Paris.
1877. Professor H. L. F. Helmholtz. Berlin.
1868. A. Heynsius. Leyden.
1872. J. E. Hilgard, Assist.-Supt. U.S. Coast Survey. Washington.
1861. Dr. Hochstetter. Vienna.
1876. Professor von Quintus Icilius. Hanover.
1867. Dr. Janssen. 21 Rue Labat (18° Arrondissement), Paris.
1876. Dr. W. J. Janssen. The University, Leyden.
1862. Charles Jessen, Med. et Phil. Dr., Professor of Botany in the University of Greifswald, and Lecturer of Natural History and Librarian at the Royal Agricultural Academy, Eldena, Prussia.
1876. Dr. Giuseppe Jung. Milan.
1877. M. Akin Kàroly. 5 Babenbergerstrasse, Vienna.
1862. Aug. Kekulé, Professor of Chemistry. Ghent, Belgium.
1861. M. Khanikof. 11 Rue de Condé, Paris.
1866. Dr. Henry Kiepert, Professor of Geography. Berlin.
1873. Dr. Felix Klein. Munich, Bavaria.
1874. Dr. Knoblauch. Halle, Germany.
1868. Professor Karl Koch. Berlin.
1856. Professor A. Kolliker. Wurzburg, Bavaria.
Laurent-Guillaume De Koninck, M.D., Professor of Chemistry and Palæontology in the University of Liége, Belgium.
1877. Dr. Hugo Kronecker, Professor of Physiology. 57 Sidonien-strasse, Leipzig.
Dr. Lamont. Munich.
1876. Professor von Lasaulx. Breslau.
1872. Georges Lemoine. 19 Rue du Sommerard, Paris.
1877. Dr. M. Lindeman, Hon. Sec. of the Bremen Geographical Society, Bremen.
1846. Baron de Selys-Longchamps. Liége, Belgium.
1857. Professor Elias Loomis. Yale College, New Haven, United States.
1871. Professor Jacob Luroth. Carlsruhe, Baden.
1871. Dr. Lutken. Copenhagen.
1869. Professor C. S. Lyman. Yale College, New Haven, United States.
1867. Professor Mannheim. Rue de la Pompe, 11, Passy, Paris.
1867. Professor Ch. Martins, Director of the Jardin des Plants. Montpellier, France.
1862. Professor P. Merian. Bâle, Switzerland.
1846. Professor von Middendorff. St. Petersburg.
1848. Professor J. Milne-Edwards. Paris.
1855. M. l'Abbé Moigno. Paris.
1877. Professor V. L. Moissenet. L'École des Mines, Paris.
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